This document is guaranteed to be current only to issue date.

Some Mars Global Surveyor documents that relate to flight operations are under revision to accommodate the recently modified mission plan.

Documents that describe the attributes of the MGS spacecraft are generally up-to-date.

Mars Global Surveyor

Mission Operations Specification

Volume 1: System

Final

Date: September 1, 1995

Jet Propulsion Laboratory
California Institute of Technology

JPL D-12369, Vol. 1

542-409

MARS GLOBAL SURVEYOR

MISSION OPERATIONS SPECIFICATION

VOLUME 1: SYSTEM

Final

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September 1, 1995

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TABLE OF CONTENTS

FIGURES

TABLES

ACRONYM LIST

ABM	Aerobraking Maneuver
ADPE	Automated Data Processing Equipment
AMMOS	Advanced Multimission Operations System
CMDPKF	Command Packet File
CCSDS	Consultative Committee for Space Data Systems
CO-I	Co-Investigator
DACE	Data Acquisition and Command Element
DAT	Data Administration Team
DSN	Deep Space Network
DSNO	DSN Operations m
DSO	Data System Operations
DSRE	Data Storage and Retrieval Element
EAE	Engineering Analysis Elements
EDF	Engineering Data Formatter
EUA	External User Access
FPO	Flight Projects Office
FPSA	Flight System Performance Analysis
FSDM	Flight Software Analysis
FSV	Flight Sequence Verification
GDS	Ground Data System
GFE	Government Furnished Equipment
GSFC	Goddard Space Flight Center
GSMCC	Ground System Monitor Control and Configuration
HEF	High Efficiency
ICD	Interface Control Document
IDS	Interdisciplinary Scientist
LAE	Long Term Archive Elements
LAN	Local Area Network
MC	Mission Control
MD	Mission Director
MGDS	Multimission Ground Data System
MGSO	Multimission Ground System Office
MO	Mars Observer
MOA	Mission Operations Assurance
MOI	Mars Orbit Insertion
MOIS	Mission Operations Information System
MOS	Mission Operations System
MOSC	MOS Interactive Command
MOSDT	MOS Design Team
MSA	Mission Support Area
NAE	Navigation Analysis Element
NAIF	Navigation Ancillary Information Facility
NASCOM	NASA Communications
NAV	Navigation Team
NIPC	Non-Interactive Payload Command

ACRONYM LIST (cont'd)

NSC	Non-Stored Command
OIA	Operations Interface Agreement
ORT	Operational Readiness Test
OTM	Orbit Trim Maneuver
PDB	Project Data Base
PDS	Planetary Data System
PI	Principal Investigator
POSA	Primary Operations Support Area
PS	Participating Scientist
PSE	Planning and Sequencing Element
RMSA	Remote Mission Support Area
RSST	Radio Science Support Team
RTO	Real-Time Operations
SASF	Spacecraft Activity Sequence File
SCIC	Spacecraft Interactive Command
SCMF	Spacecraft Message Files
SCP	Standard Control Processor
SCT	Spacecraft Team
SDA	Science Data Analysis
SEQ	Sequence Team
SEQ_GEN	Sequence Generation
SEQTRAN	Sequence Translation
SFDU	Standard Data Formatted Unit
SIS	Software Interface Specification
SIT	Science Investigation Team
SOPC	Science Operations and Planning Computer
SOT	Science Operations Team
SPAE	Science Planning and Analysis Element
SPAS	Spacecraft Performance Analysis Software
SPICE	Spacecraft, Planet, Instrument, C-matrix, Event Information
STL	Spacecraft Test Laboratory
SSC	Stored Sequence Commanding
SSE	Science Support Element
SSR	Solid State Recorder
TCM	Trajectory Correction Maneuver
TDA	Tracking and Data Acquisition
TDS	Tracking Data System
TL	Team Leader
TMOD	Telecommunications and Mission Operations Directorate
U/L	Uplink
VOCA	Voice Operations Communications Assembly
VTE	Verification and Test Element

SECTION 1.0

INTRODUCTION

The process of operating a spacecraft to achieve the mission objective is defined as Mission Operations. Included in this process is the operation of the MGS spacecraft, instruments and the ground system. The Mission Operations System (MOS) is composed of the ground hardware, software, facilities, personnel, plans and procedures essential to Mission Operations.

The process used by the science investigators in determining and reporting scientific results is not a part of the MOS.

The MGS Mission Operations System Design Team (MOSDT) will be the mechanism for coordinating the design and implementation of the project MOS. The MOSDT will also coordinate with the services provided by Telecommunications and Mission Operations Directorate (TMOD). The MOSDT is comprised of members from each functional area in support of MOS development.

The primary goal of the MOS is to produce an operational system that provides the required project capabilities while minimizing overall MOS costs.

1.1 PURPOSE AND SCOPE

The purpose of this document is to specify and control the Mars Global Surveyor process requirements, design and operation of the MOS to perform Mission Operations in accordance with the applicable documents identified in Section 1.4. All operational functions/processes required to control the spacecraft bus, science instruments and ground system for accomplishing the mission objectives are identified.

Presented through a series of twelve volumes are: the ground system, operations processes and organization, interfaces, operating procedures, flight rules, spacecraft operating information, test plans, and training plans. Functions performed directly by the project (i.e., funded or operated by the project) are presented, including those performed by the spacecraft system contractor Lockheed Martin (Denver) and by the science investigators up to the point of performing science data analysis. Further details on the implementation of the project funded software and hardware is contained in separate documents as identified by the Software Management Plan 542-SW-001. Services performed by TMOD are defined at the interface level with the MOS. Detailed implementation requirements addressing these institutional services are found in the Detailed Mission Requirement (DMR) and Project Requirements/MGSO Support Plan (PRMSP).

This document does not levy requirements on the Delta II 7925 launch vehicle or its operations.

1.2 DOCUMENT DESCRIPTION

The Mission Operations Specification is composed of 12 volumes. The first 3 volumes present the design and specify the requirements on the project elements and TMOD. The next 5 volumes respond to these requirements by defining the procedures to be followed; controlling all MOS interfaces; defining the operating facility; and establishing the project test and training plans. The last 4 volumes provide user guides containing material on commanding the spacecraft, interpreting the telemetry, contingency plans, flight rules, and flight software. Figure 1-1 illustrates the document composition.

Volume 1 - SYSTEM presents the top level view of Mission Operations. Included are MOS system requirements, identification of the MOS processes, operations organization, and system performance. An appendix covers the MGS operations concepts.

Volume 2 - DATA SYSTEM specifies the components that comprise the Ground Data System (GDS) and project supplied elements. Presented are software and hardware functional block diagrams; configurations for pre-launch test support, launch operations (as appropriate) and mission operations; interface summary covering MGSO, TDA, Planetary Data System, Project elements; and requirements on the project Science Operations Planning Computer (SOPC).

Volume 3 - OPERATIONS defines the requirements to support MGS operations and allocates requirements specified in Volume 1 to the Mission Operations processes and sub-processes. This document also defines the operations flight team and team positions required to execute those processes.

Volume 4 - PROCEDURES contains the procedures describing the detailed steps and checklists that must be performed to complete the ground operations tasks. These detailed procedures are in direct response to the requirements identified in Volume 3.

Volume 5 - INTERFACES contains all the MOS interfaces. These interfaces are controlled by Interface Control Documents (ICDs), Software Interface Specifications (SISs) and Operational Interface Agreements (OIAs). Included are interfaces with the spacecraft, MGSO, PDS, TDA and science investigators.

Volume 6 - TEST contains the detailed plans to be followed for each of the project conducted tests identified by Volumes 1 and 2. Included are the Flight

Sequence Verification tests, MOS Compatibility tests and the identification of the institutional tests performed prior to the project tests.

Volume 7 - TRAINING contains the detailed plans and procedures to be followed for each of the project conducted training events identified in Volumes 1 and 3. Also identified are the related institutional training activities that are performed prior to project training.

Volume 8 - FACILITY contains a description of the facilities required by the user at JPL and at the remote user locations. Included is a summary of the communication links between JPL and the remote users.

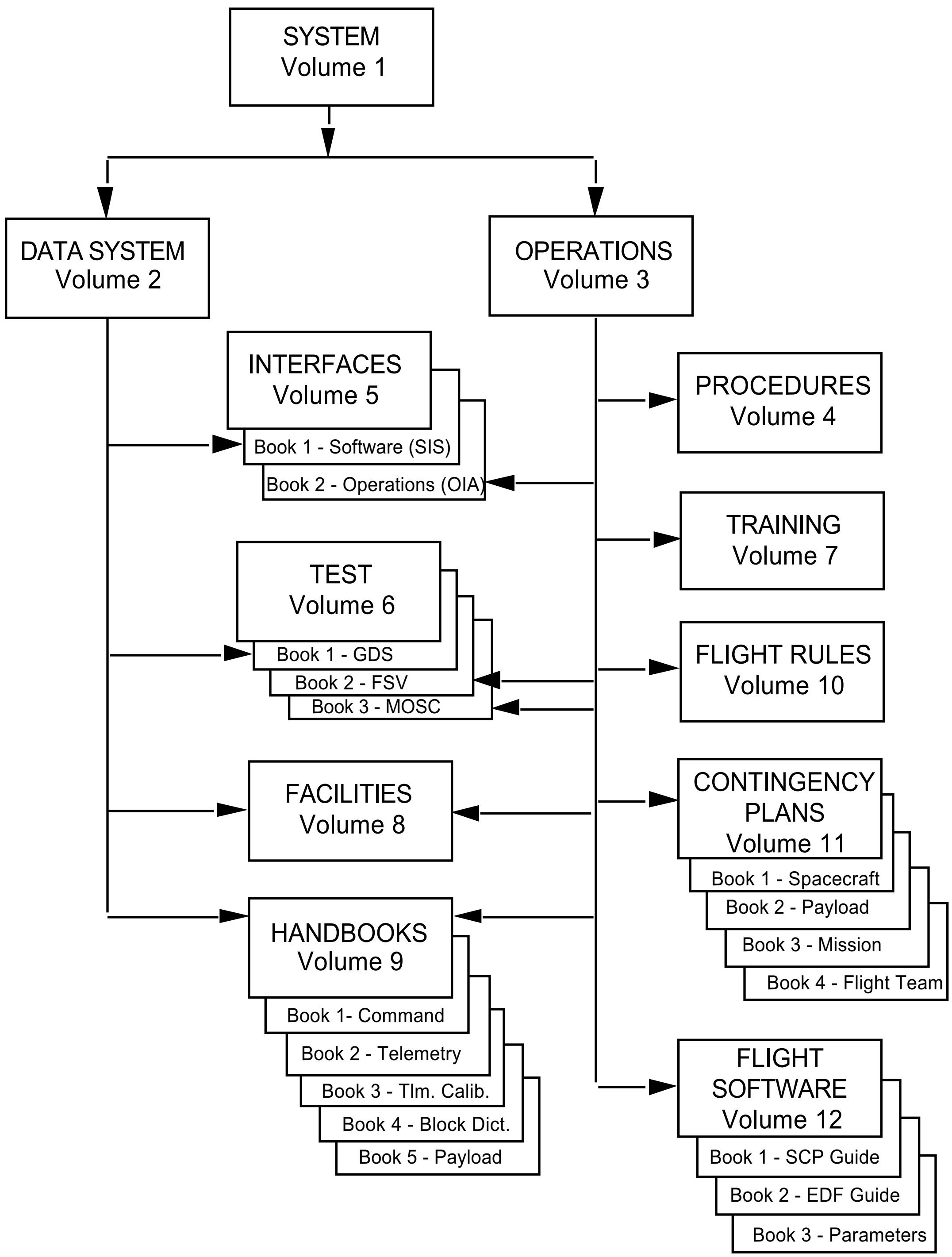
Volume 9 - COMMAND & TELEMETRY HANDBOOK contains spacecraft development documents that describe telemetry measurements, block definitions, commands and other information of interest to operations personnel.

Volume 10 - FLIGHT and MISSION RULES contains the flight operating rules and constraints for the spacecraft, payload and mission system.

Volume 11 - CONTINGENCY PLANS contains the plans to be used in the event the nominal plans can not be followed. Separate sections address the spacecraft, payload, mission and flight teams.

Volume 12 - FLIGHT SOFTWARE contains the user guides for the SCP and EDF spacecraft computers. Included are system descriptions and flight software parameters.

Figure 1-1 Mission Operations Specification Structure



1.3 RELATIONSHIP TO OTHER DOCUMENTS

This document forms the basis for and design specification of mission operations and is compatible with the Mission and Navigation Plans. The project Mission Requirements Document (MRD) and Investigation Description Science Requirements Document (IDSRD) form the requirements on the MOS. The Mission Requirements Request (MRR) and MGSO Support Agreement reflect requirements on the Telecommunications and Mission Operations Directorate. TMOD response documents (Detailed Mission Requirement (DMR), Network Operations Plan, and Project Requirements/MGSO Support Plan) are companion documents reflecting requirements and commitments of institutional support. Figure 1-2 shows the relationship between these documents and the Mission Operations Specifications.

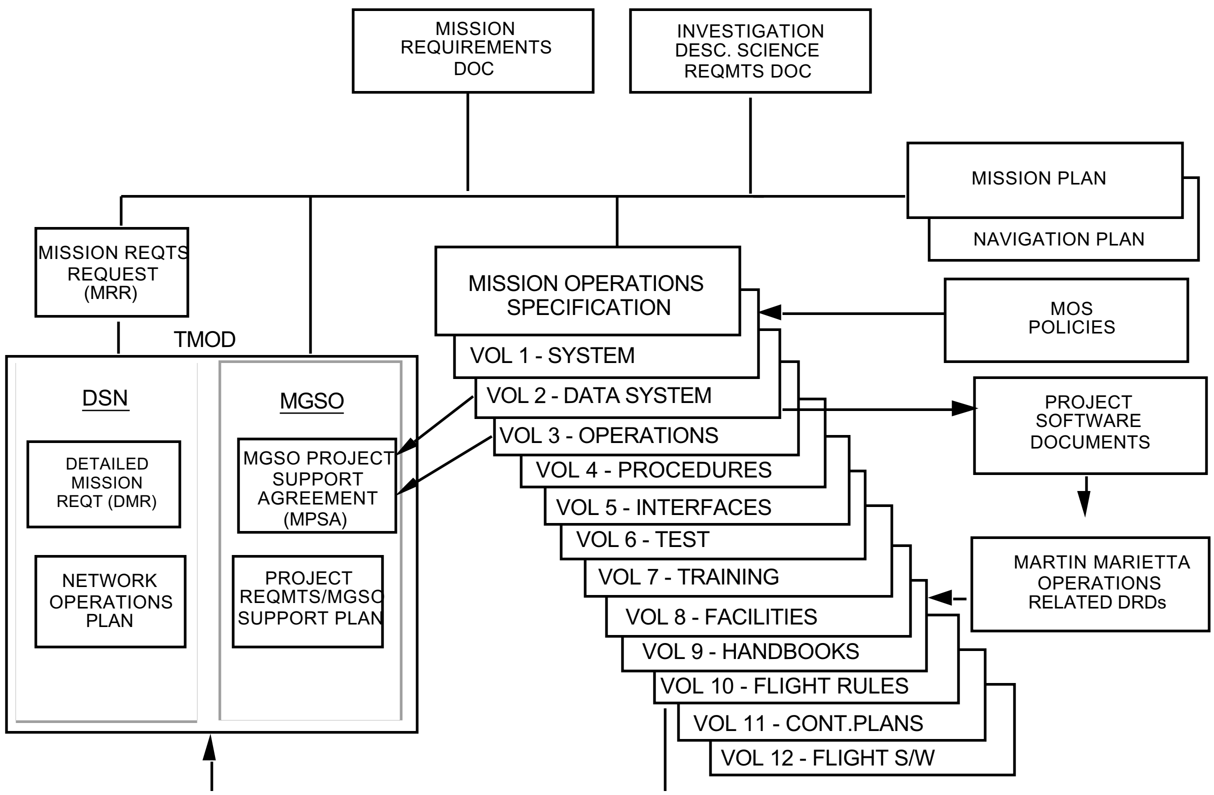


Figure 1-2
MOS Specifications Relationship to Other Documents

1.4 APPLICABLE DOCUMENTS

The latest issue of the following JPL documents are applicable to all functional requirements contained within this document. The MOS design shall be responsive to these documents.

542-100	Project Plan
542-110	Project Policies and Constraints
542-423	Mission Operations Policies
542-400	Mission Requirements Document
542-303	Investigation Description & Science Requirements Document

The following documents contain information pertaining to mission operations. The design of the MOS is required to be compatible with these documents.

542-405	Mission Plan
542-406	Navigation Plan
542-200	Spacecraft Requirements
810-5	DSN/Flight Project Interface Design Book, Volumes I and II
D-1350	JPL Information System Standards
820-13	DSN System Requirements Detailed Interface Design
542-412	Mission System Configuration Management Plan

SECTION 2.0

GUIDELINES

This section provides the guidelines pertaining to the design and operations of the MOS. These guidelines, along with the requirements, form the basis for the MOS to achieve its goal of "cheaper, better, faster" operations given that the science operations are distributed and the spacecraft team operations are remote.

For the purpose of this document, a guideline is defined as a recommendation to be followed unless resources are affected. If there is a conflict or extra resources are required, the Mission System Manager will resolve the issue.

2.1 MOS GUIDELINES

2.1.1 INHERITANCE

The MGS MOS will use the Mars Observer inheritance where it is realistic to do so and is cost effective. The operational areas that worked well on Mars Observer should be maintained and enhanced.

2.1.2 STAFFING

In order to keep the operational costs low, the operations staff will be reduced by 40% from Mars Observer. This reduction will be achieved by re-engineering the processes, using enabling technologies, reducing management, incorporating lessons learned, using experienced staff, and using multi-mission support where available.

2.1.3 MULTI-MISSION GROUND DATA SYSTEM

The MOS will require the AMMOS Version 4.3 baseline for launch. TMOD-MGSO will maintain the MGS core and update as required to maintain compatibility with the latest multi-mission updates and features. The Project will accept MGSO upgrades on a schedule that does not interfere with mission operations.

2.1.4 MISSION SYSTEM DEVELOPMENT & COMPLETION

The multi-mission ground data system and supporting software will be complete for the launch and cruise phase prior to launch. Due to budgetary constraints, development of some encounter capabilities will be delayed and delivery will take place in the middle of-cruise, thereby completing the ground data system.

2.1.5 OPERATIONS SIMPLIFICATION

The MGS operations should be simplified and automated where possible.

2.1.6 TECHNICAL QUALITY MANAGEMENT (TQM)

Technical Quality Management should be applied throughout the mission to increase productivity as processes/functions become better understood.

SECTION 3.0

MISSION SYSTEM OVERVIEW

This section presents a high level overview of the Mission System, the operations associated with each process and the requirements levied on each process. Some of these operations and services are performed by the project, others by TMOD personnel. The mission system is composed of ground hardware and software, facilities, people and operations procedures all working together to capture Mars science data from the MGS spacecraft to be analyzed for scientific advancement.

3.1 MISSION SYSTEM PROCESSES AND PROCESS REQUIREMENTS

The MGS Mission System is composed of seven subprocess elements: MOS Management; Mission and Navigation Design; Uplink; Downlink; Archive of Science and Engineering Data; Ground System Development and Maintenance; and Mission Operations Assurance. Figure 3-1 depicts the Mission System Process Map. These processes together provide the framework for the Mission Operations System.

Mission System Requirements:

(1) The Mission System shall have processes in place to operate the MGS spacecraft for the four phases of the mission, namely, cruise, aerobraking, mapping and relay.

(2) The Mission System shall operate within the allocated budget.

3.1.1 MOS MANAGEMENT

The MOS Management Process provides all operations management functions (including management of teams) to the flight team and interacts with all of the MOS elements. This process receives requests for information, budget guidelines and requirements from project management, as well as MOS status from the flight team. These input products are processed at weekly status meetings and at MOS reviews to produce the MOS staffing and budget plan, MOS schedules, and daily technical direction to the flight team.

MOS Management Requirements:

(1) The MOS Management Process shall provide all management functions required to operate the MGS mission.

(2) The process shall provide the primary path for upward reporting.

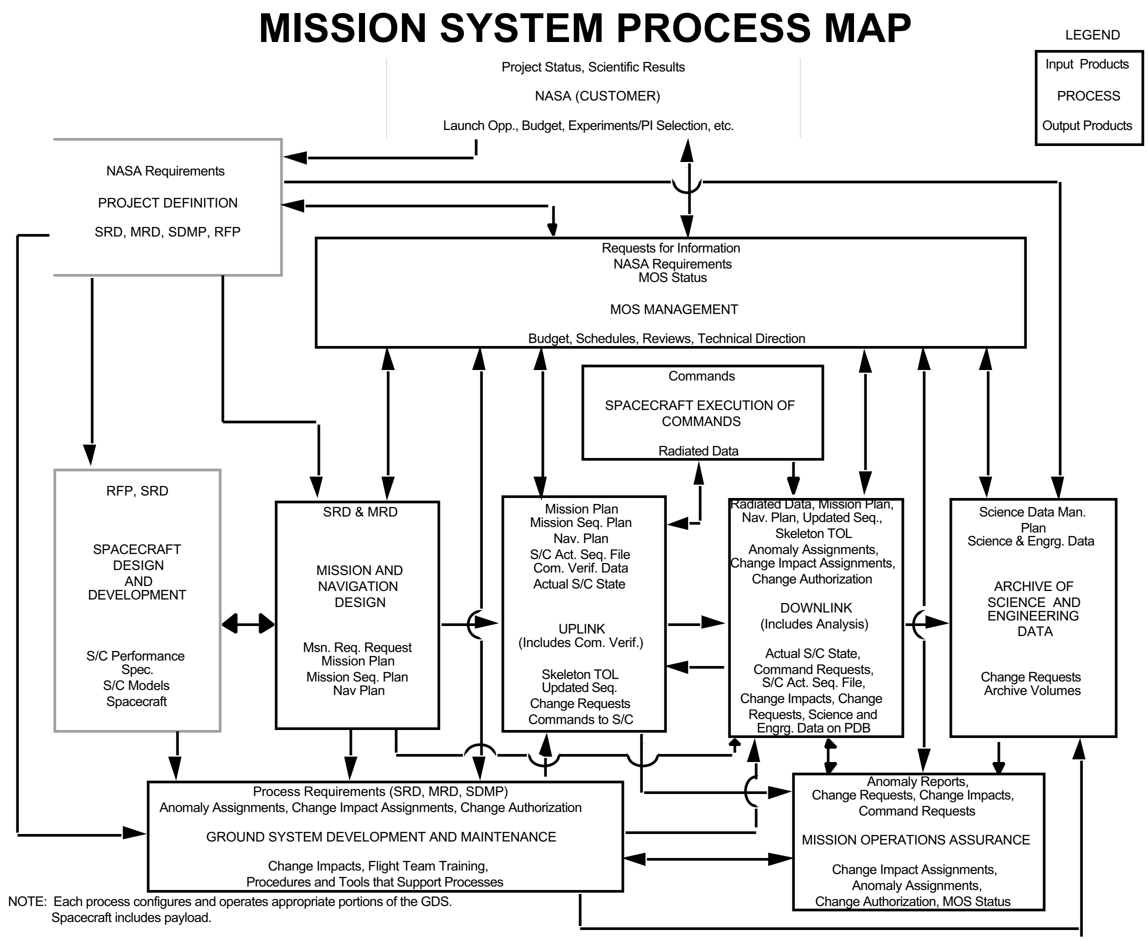


Figure 3-1 Mission System Process Map

3.1.2. MISSION AND NAVIGATION DESIGN

The Mission and Navigation Design (M&ND) process receives as input top-level requirements from the Project Plan and the Investigation Description and Science Requirements Document (IDSRD). From these top-level requirements, the Mission Design process generates the Mission Requirements Document (MRD), which captures the requirements on the Mission System, comprised of mission design, navigation design and mission operations development. The MRD additionally generates requirements on the other project systems, including the spacecraft system, science system, launch system, and Mission Operations Systems Office. The mission support requirements for the Tracking and Data Acquisition system are captured in the Mission Requirements Request (MRR).

The M&ND process uses the MRD as the source requirements for the generation of the Mission Plan (MP) and the Navigation Plan (NP). These plans document the mission and navigation detailed design. Finally, from the Mission Plan, the M&ND process generates the Mission Sequence Plan (MSP) which contains the detailed flight sequence design for each stored sequence. This sequence design will be documented as a timeline (with block call placeholders, for details to be filled out later as the design matures).

Mission and Navigation Design Requirements:

(1) The M&ND Process shall generate the Mission Requirements Request, Mission Plan, Mission Sequence Plan, and Navigation Plan.
(2) The Mission Sequence Plan shall be refined for each stored sequence prior to entering the uplink process and documented in an electronic SEQ_GEN readable format.

3.1.3 UPLINK PROCESS

The Uplink Process provides the mechanism for sequencing and commanding the MGS spacecraft. The process includes four basic subprocesses: Stored Sequence Commanding (SSC), Non-stored Commanding (NSC), Command Radiation, and Command Verification. Each of these subprocesses is described below. See Figure 3-2 for Uplink Process Map.

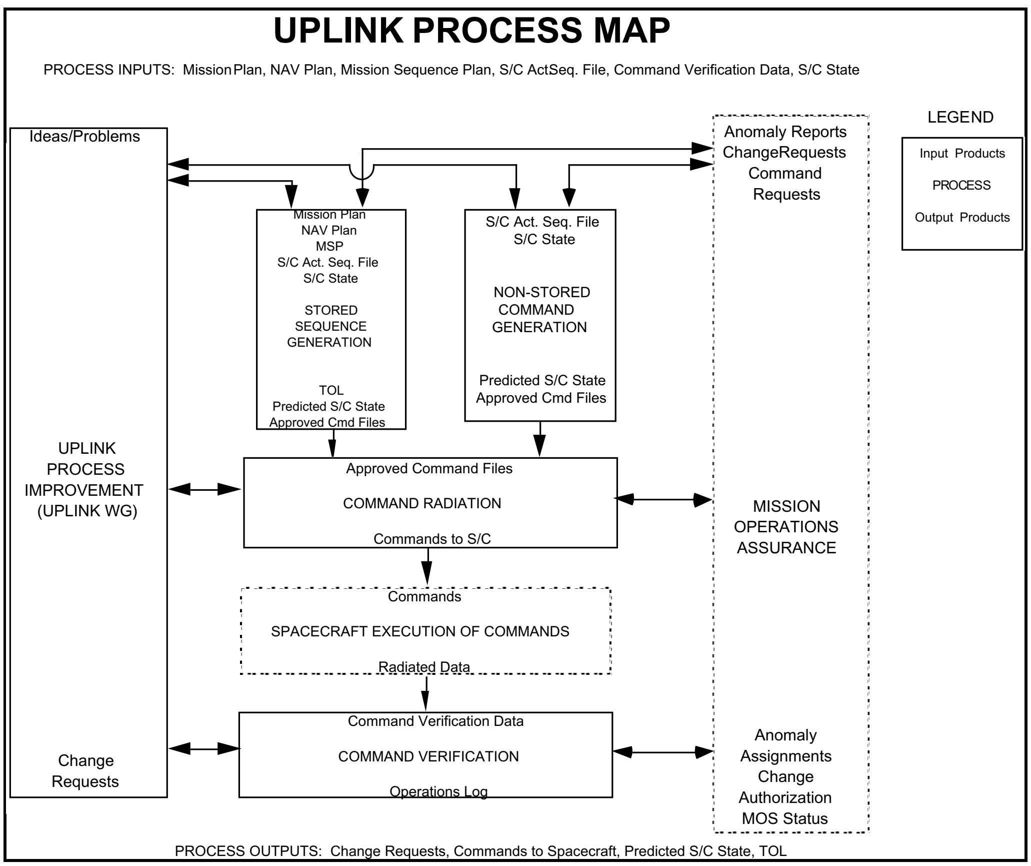


Figure 3-2 Uplink Process Map

For Mars Global Surveyor the primary method for controlling spacecraft bus activities will be through on-board stored sequence commands. As necessary, stored sequence activities will be supplemented by non-stored commands. Science instruments will primarily be sequenced using the non-stored commanding process.

The specific Uplink processes are defined in Volume 3.

Uplink Process Requirements:

(1) Standard spacecraft operations shall be conducted using the uplink process, (where command sequences and non-stored commands are developed and tested in advance of execution on the spacecraft) according to the approved standard command and sequence generation process.
(2) The uplink process shall develop a criteria to determine which types of commands need validation.
(3) Multi-mission tools shall provide the core of the sequencing system, with MGS adaptation using Unix workstations.
(4) The uplink process shall provide the project with the ability to build stored sequences and non-stored commands in a repetitive, timely, efficient manner that is compatible with the mission plan.
(5) The uplink process shall accept command/sequence inputs from distributed science/engineering teams via the project database.
(6) The uplink process shall use the latest technology/techniques available for sequencing that fit within the project budget.
(7) The uplink process shall be able to handle sequence change requests.
(8) The uplink process shall track initial and final spacecraft states using sequencing software.
(9) The uplink process shall accommodate DSN coverage loss with a minimum amount of human intervention.

3.1.3.1 STORED SEQUENCE PROCESS

The Stored Sequence development process takes the mission sequence plan, science and engineering inputs and develops them into an integrated sequence to be stored in spacecraft memory. The process uses two passes through the software. See Figure 3-3 for details. Pass one begins with the sequence planning phase (3 weeks), followed by a short sequence integration phase and ends with a sequence review and Spacecraft Test Laboratory (STL) loading or STL run. Pass two includes a rerun of the sequence to accommodate changes of a corrective nature found during the pass one review and simulation run, to implement approved change requests and to incorporate approved late updates (e.g. maneuver parameters) to the sequence.

Stored Sequence Process Requirements:

(1) All inputs to the stored sequence process shall be placed on the PDB for pick up by the Sequence Team.

(2) Files required to develop the stored sequence shall be electronically tracked.

(3) Stored sequences shall be verified by loading them on STL. In addition some activities (i.e. TCMS) shall be validated by running them through STL.

(4) The stored sequence command file shall be placed on the PDB a minimum of 2 hours prior to the track period for which the file is to be sent.

(5) A standard mapping stored sequence shall execute for a period of 28 days. Cruise sequences may vary in length due to TCM placement and cruise activities.

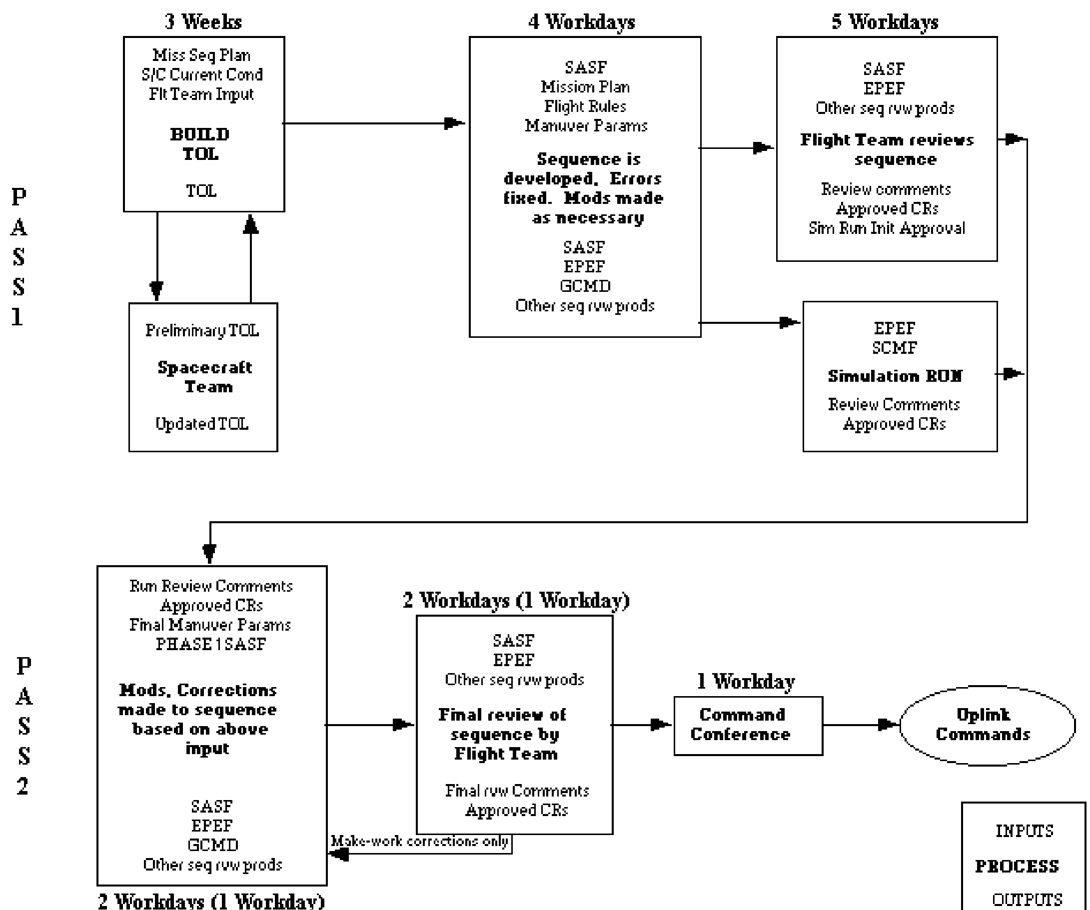


Figure 3-3
STORED SEQUENCE PROCESS

3.1.3.2 NON-STORED COMMANDING PROCESS

Non-stored commanding (NSC) will be used as a supplementary method of spacecraft control. As its name implies, non-stored commanding involves the sending of commands to the spacecraft which are not stored in the onboard bus memory, but rather are executed upon receipt by the spacecraft.

Non-stored commands are subcategorized into four subtypes and are grouped according to the level of processing they require. These are Non-interactive Payload Commands (NIPC), Express Commands (EC), Coordinated Commands (these include spacecraft interactive and MOS interactive commands) and Pre-Approved Commands (PAC). Each type of NSC has a defined amount of rigor applied to its processing. NIPCs are processed with the least amount of flight team rigor. This is as a result of their non-interactive nature. The processing of ECs, Coordinated Commands and PACs is more rigorous because of their interactive nature and the possibility that such commands could damage the spacecraft or an instrument, resulting in loss of data or mission goals.

Non-stored commands will be initiated by members of the flight team. In the case of NIPCs, the science teams will create the SASFs containing their desired commands. For ECs, Coordinated Commands and PACs, the downlink process (SCT and science teams) will create the necessary SASF. After the requesters install their SASFs onto the PDB, the uplink process will retrieve the files and prepare them for transmission to the spacecraft. The processing of NSCs will be extremely automated. NIPC processing will be fully automated and shall require approximately ten minutes to process an SASF extracted from the PDB into a GCMD ready for transmission to the spacecraft. The NIPC and EC processes shall require little or no hands-on interaction beyond the requester installing the file onto the PDB. Coordinated Command processing will require more rigor since commands are interactive with the spacecraft and/or ground. However, this manipulation will be reduced to only that level necessary to accomplish the processing and mitigate risk of erroneous or inappropriate commands reaching the spacecraft. PACs will have been pre-approved for use by subsystem level members of the flight team and will be available as CMD_PKT files on the PDB. Their effects on the spacecraft will have already been verified by an earlier treatment as a Coordinated Command and will, therefore, only require a simple communication to the Mission Manager for transmission approval.

Non Stored Commanding Requirements:

(1) All non-stored command generation shall be automated to the fullest extent possible.
(2) Non-Stored commanding shall require installing a SASF on the PDB to begin the process.
(3) All Non-Stored commands shall be defined such that command initiator knows which type of command he/she is requesting.

(4) All files generated from initial SASF input, to development of a GCMD shall be electronically tracked.
(5) NIPC commands shall only be requested by each payload science team for their respective instrument.
(6) NIPC command processing (from PDB pickup to command packet readiness) shall not exceed 15 minutes.
(7) Spacecraft Interactive commands shall be validated through STL.

3.1.3.3 COMMAND RADIATION PROCESS

The Command Radiation process is responsible for ensuring the Ground System is appropriately configured with the correct parameters and settings (e.g. standards and limits, transmitter power and frequency, command file names, command modulation on, radiation windows etc.) to radiate a command to the spacecraft.

Command Radiation Process Requirements:

(1) The Command Radiation process shall supply the input to the S/C execution process.
(2) The Command Radiation process shall electronically document all significant steps in this process.
(3) Command radiation shall be performed as quickly as possible based upon the number of commands, the command prioritization and DSN track availability.
(4) Command radiation for stored sequence loads shall be performed within the allocated radiation window.
(5) This process shall keep an archive of all commands sent to the spacecraft via the command tracking database.
(6) Command/sequence radiation approval shall be given by the Mission Manager.

3.1.3.4 COMMAND VERIFICATION PROCESS

The Command Verification process is responsible for confirmation of receipt by the spacecraft of commands radiated by the Command Radiation process.

Command Verification Process Requirements:

(1) The Command Verification Process shall be accomplished by direct and/or indirect telemetric means as quickly as possible.
(2) The Command Verification Process shall electronically document all steps in this process.

3.1.4 DOWNLINK PROCESS AND REQUIREMENTS

The MOS downlink design is based on the following important mission, spacecraft and instrument operating characteristics.

a. Repetitive, non-adaptive mapping mission with multiple opportunities for science observations.
-An overall data return of 70% is acceptable.
-Daily spacecraft solid state recorder playbacks during mapping.
-Real-time downlink telemetry transmission every three days and during pre- and post-playback periods during mapping.
-10 radio science observations per day nominally during mapping.

b. Full use of Institutional TMOD services.
-Monitor spacecraft health whenever spacecraft is being tracked.
-Send project approved commands and stored sequences.
-Normal project staffing is single shift, 5 day week.

c. Spacecraft and ground comply with JPL Data Standards.
-Channel Coding, Packet Telemetry and SFDU implementation.

d. Distributed science operations.
-Scientists receive and process data at their home institution.
-Scientists communicate through the Project Data Base.
-Scientists will archive data products directly to the PDS.

The Downlink process includes five principal subprocesses: Navigation Analysis (NA), Flight System Performance Analysis (FSPA), Ground System Monitor, Control and Configuration (GSMCC), Science Data Analysis (SDA) and Flight Software Development & Maintenance (FSDM). The Downlink Process Map is shown in Fig. 3-4.

Spacecraft telemetry (including packetized science data), radiometric, open loop radio science, and monitor data are acquired and placed in the Project Data Base during the GSMCC subprocess. Along with other supporting operational data, this data (from the PDB) is input to the Navigation Analysis, the Flight System Performance Analysis, the Science Data Analysis and the Flight Software Development and Maintenance subprocesses.

Downlink process inputs include the Mission Plan, Navigation Plan, Mission Sequence Plan, telemetry, and open loop radio science and radiometric data from the spacecraft. Downlink process outputs include spacecraft, instrument and ground system state/status definition, Spacecraft Activity Sequence Files (SASFs), change requests and command requests.

The specific functions performed in the Downlink process are defined in MOS Specification Vol. 3.

Downlink Process Requirements:

(1) The Downlink Process shall provide data (raw science packetized data and raw channelized engineering data) to the PDB within 24 hours after the end of the track where the data was downlinked. The data will be in time order and gap-filled. The 24 hour allocation is distributed into two 12 hour pieces, one to the TMOD-DSN and the other to TMOD-MGSO.

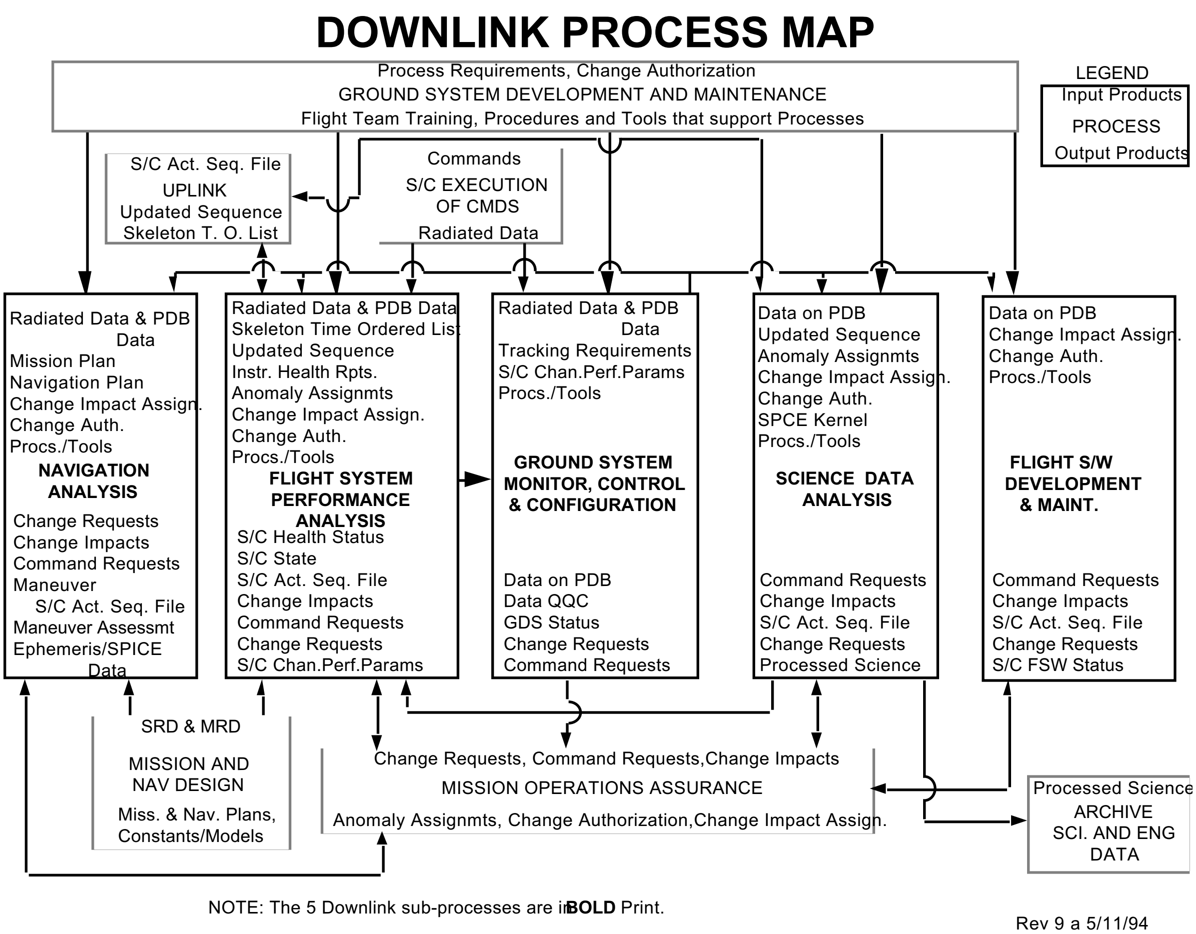


Figure 3-4 Downlink Process Map

(2) The Downlink Process (end to end) shall provide 870% overall data return. This process shall strive for the best end-to-end performance possible, but will allow for human error and mechanical/hardware failure. The breakdown below shows acceptable minimum performance levels in each area affecting downlink:

S/C	86%
TMOD -DSN	95%
TMOD-MGSO	99%
D/L Operations	86%
Total Return	70%

3.1.4.1 NAVIGATION ANALYSIS

The Navigation Analysis process shall design and implement maneuvers necessary to place the spacecraft in an orbit about Mars, maintain orbit accuracy, determine the spacecraft position with respect to the planet, predict the spacecraft future position in orbit and generate all necessary navigation products to perform the above mentioned tasks.

Navigation Analysis Requirements:

(1) The Navigation Analysis Process shall provide maneuver design and implementation to place the MGS spacecraft in orbit about Mars.
(2) The Navigation Analysis process shall be able to generate aerobraking maneuver solutions on a daily basis, if required.
(3) Through the mapping phase, knowledge of the actual spacecraft position shall be determined within 10 working days of tracking data receipt to an accuracy of 9 km down track, 5 km cross track and 2 km radial.
(4) Navigation products (i.e. SPICE kernel data) shall be generated and distributed to the users within 10 days of packet downlink.

3.1.4.2 FLIGHT SYSTEM PERFORMANCE ANALYSIS (FSPA)

The Flight System Performance Analysis process shall provide the technical analysis of spacecraft performance (including instrument) both real-time and non-real time. Anomaly planning analysis and resolution is included in this process with the intent to reduce spacecraft risk and, in the event of an anomaly, to provide a work around solution which enables the spacecraft to complete the mission objectives. The primary external inputs to this process are spacecraft telemetry and science instrument health status. The process utilizes a variety of spacecraft analysis software, TMOD-MGSO tools, MOS procedures and plans. Principle outputs are spacecraft status reports, logs, problems reports, and command and sequence inputs to the Uplink Process.

Flight System Performance Analysis Requirements:

(1) The Flight System Performance Analysis process shall provide information on health and performance for the spacecraft and instruments.

(2) Spacecraft pointing reconstruction shall be performed by this process.
(3) The FSPA process shall use the Spacecraft Performance Analysis Software (SPAS) in performing spacecraft trend analysis.
(4) Anomaly analysis shall be performed by this process.
(5) Spacecraft engineering sequence inputs shall be provided.

3.1.4.3 GROUND SYSTEM MONITOR, CONTROL AND CONFIGURATION

The Ground System Monitor, Control and Configuration (GSMCC) process consists of obtaining data from the spacecraft telemetry, open loop radio science and tracking information, scheduling and coordinating MGSO and Project support for MGS specified activities, monitoring spacecraft health and ground performance for proper operation, and sending project authorized commands.

Ground System Monitor, Control and Configuration Requirements:

(1) The telecommunications link performance confidence shall be ~ 95% for all engineering and science events.
(2) Twenty-four hour tracking shall be provided by the GSMCC process for Mars Orbit insertion and aerobraking.
(3) 34M HEF or equivalent shall be scheduled to provide the one DSN pass/day and two passes every third day for mapping.
(4) 70 M stations shall be scheduled when the telecom link does not meet 95% confidence with a HEF at the lowest science or engineering data rate.
(5) An automated notification of key personnel shall exist for unattended spacecraft health parameter monitoring.

3.1.4.4 SCIENCE DATA ANALYSIS

The Science Data Analysis process shall be performed by the Principal Investigators (at their home institutions), using their own tools. The PIs shall provide processed data to the PDS (in electronic form).

3.1.4.5 FLIGHT SOFTWARE DEVELOPMENT & MAINTENANCE (FSDM)

The Flight Software Development and Maintenance process shall be responsible for providing support for spacecraft activities, requirements generation, implementation and tracking the state of the spacecraft flight software. The external inputs to the process are change requests, sequence products, and PDB data.

FSDM Requirements:

(1) The FSDM process shall use the MO flight software as a baseline and make the necessary changes for the MGS spacecraft.

(2) The FSDM process shall be performed by the MGS contractor - Lockheed Martin during operations.
(3) The MGS flight software shall be tested with the ground system for compatibility according the Project schedule.
(4) The FSDM process shall generate the requirements for the MGS flight software.
(5) The flight software shall be capable of modification as required (in flight).

3.1.5 ARCHIVE OF SCIENCE AND ENGINEERING DATA (ASED) PROCESS

The Archival of Science and Engineering Data process distributes the engineering and science data to the scientists for analysis and archives the same data. The science and engineering data are placed on the PDB for each investigator to electronically access and transfer to his/her own institution. Once each science investigator has processed the data, he/she shall send reduced data and products directly to the Planetary Data System node for public access.

ASED Requirements:

(1) Science and engineering data shall be available to each investigator (via the PDB) within 24 hours of downlink. The data will be “in time, on time”.
(2) Data Products (i.e. spice kernels) supporting data analysis shall be provided to the PIs via the PDB daily.
(3) Each PI shall be responsible for sending reduced data directly to the Planetary Data System. JPL shall be responsible for sending the raw engineering data, unprocessed science data, and SPICE data to the PDS.
(4) Each PI shall be responsibility for submitting his/her electronic experimenter’s notebook on a determined interval (different for each investigation) for E-Kernel production .

3.1.6 GROUND SYSTEM DEVELOPMENT AND MAINTENANCE (GSDM) PROCESS

Ground System Development and Maintenance is the process by which ground tools (hardware, software, networks documentation), procedures, facilities and training are developed for the project. The customers of this process are the uplink, downlink, archive, MOS management and mission operations assurance processes. This process shall be the same for operations and development except for reduced frequency during operations. There are four sub-processes in the GSDM process. See Figure 3-5 for the GSDM Process Map.

GSDM Process Requirements:

(1) The GSDM process shall assess change impacts and participate in the Mission Operations Assurance process.
(2) The GSDM process shall train the flight team and develop procedures and tools that support operations.
(3) MGSO deliveries shall be coordinate through the GDSM process.

GROUND SYSTEM DEVELOPMENT AND MAINTENANCE PROCESS MAP

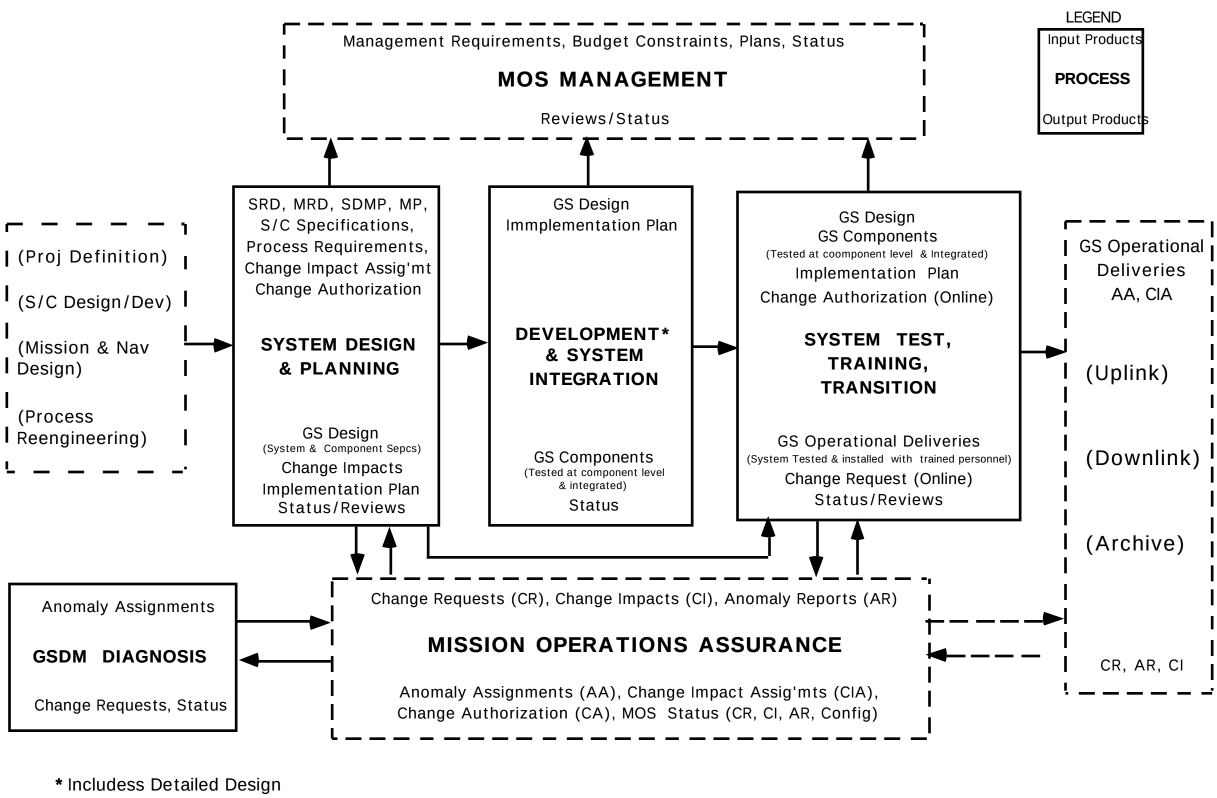


Figure 3-5 GSDM Process Map

3.1.6.1 SYSTEM DESIGN AND PLANNING (SDP)

The System Design and Planning process converts requirements (in the form of higher level specifications and authorized changes) into a ground system design (including component specifications) and an implementation plan (including a high-level ground system development schedule and work plan). The SDP process also provides change impacts in support of the Mission Operations Assurance process.

SDP Requirements:

(1) The SDP process shall development and maintain the MGS ground system design.
(2) The SDP process shall assess change requests for change impacts and make recommendations.
(3) The SDP process shall develop an Implementation Plan for developing the ground system.
(4) The SDP process shall provide management with the status of their development.

3.1.6.2 DEVELOPMENT & SYSTEM INTEGRATION (DSI)

The Development and System Integration process accepts the system design (including component specifications) and implementation plan from the SDP process. The DSI process produces, tests and integrates ground system components according to the implementation plan. The DSI process includes detailed design.

DSI Requirements:

(1) The DSI process shall provide tested and integrated ground system components to the flight team.
(2) The DSI process shall provide development status to management.

3.1.6.3 SYSTEM TEST, TRAINING AND TRANSITION (STTT)

The System Test, Training and Transition process provides flight team training, installs the system into the flight environment, tests and certifies the integrated ground system. “Operational deliveries” take place upon approval from the MOA process.

System Test, Training and Transition Process Requirements:

(1) The STTT process shall install all hardware and software for the mission system and train the operations staff to use these tools.
(2) The STTT process shall have a back-up plan in the event there is an equipment failure during a critical phase in the mission.
(3) System Test and Training shall be planned according to the Mission System Schedule.

3.1.6.4 GSDM DIAGNOSTICS

The GSDM Diagnostics process accepts anomaly assignments from the MOA process, and provides appropriate change requests and status back to the MOA.

GSDM Diagnostics Requirements:

(1) The GSDM Diagnostics process shall assess change requests and anomaly reports.
(2) The GSDM Diagnostics process shall provide diagnosis status.

3.1.7 MISSION OPERATIONS ASSURANCE PROCESS AND REQUIREMENTS

The Mission Operations Assurance (MOA) Process is divided into six subprocesses: Command Assurance, Configuration Management, Anomaly Management, System Administration, PDB Administration and Project Reporting. See Figure 3-6 for the MOA Process Map. All of these subprocesses provide mission assurance for the uplink and downlink operations, while at the same time providing a mechanism for change, and problem/failure reporting. Mission operations assurance is supported by a variety of methods, tools and personnel.

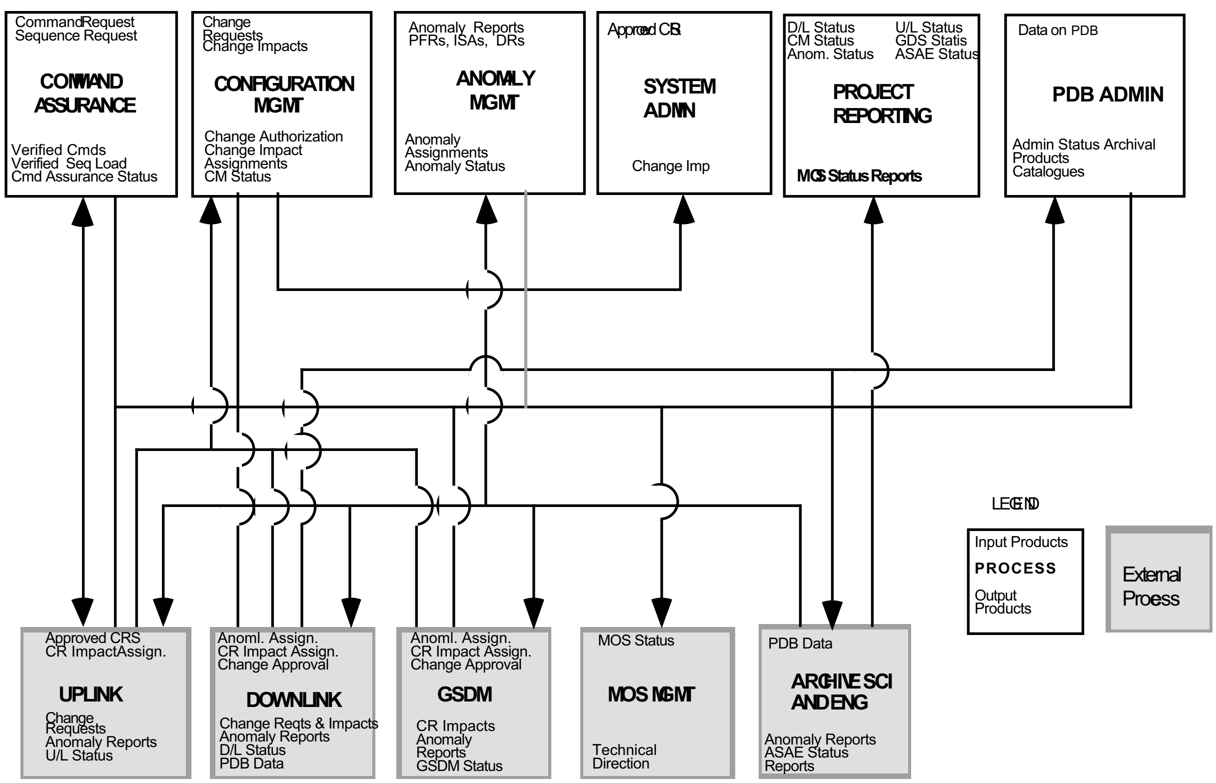


Figure 3-6 MOA Process Map

Mission Operations Assurance Process Requirements:

(1) The Mission Operations Assurance Process shall participate in all other processes as needed to assure product integrity.
(2) MOA shall use as many enabling technolgies as possible to reduce the manual labor required to perform MOA tasks.

3.1.7.1 COMMAND ASSURANCE

The Command Assurance Process provides constraint checking, and verification/ validation of commands and sequences. These services are provided through constraint checking and flight rule adherence checking in SEQ_GEN, loading and running sequences/commands through the Spacecraft Test Laboratory, flight team reviews and Mission Manager transmission approval. The Command Assurance process is distributed across team boundaries as there is no one person who performs all these tasks. Two new enabling technologies will support the Command Assurance process. They are SEQ REVIEW (which will allow electronic checking of sequences based upon each reviewer's checking parameters) and the Automated Command Tracking Toolkit (which tracks input and output files used to generate the command file sent to the spacecraft).

Command Assurance Requirements:

(1) The Command Assurance Process shall ensure no "harmful" commands are sent to the spacecraft that could lead to catastrophic failure.
(2) All new commands and unique sequences shall be verified/validated through STL before they are loaded on the spacecraft.
(3) All stored sequences shall be reviewed by the flight team prior to uplink.
(4) When a commanding/sequence error is uncovered, a check for this newly discovered error shall be added to the list of things to automatically check (using the sequence review tool) for every review.
(5) The ACT Toolkit shall be used to track the files generated in the development of the spacecraft command file.

3.1.7.2 ANOMALY MANAGEMENT

The Anomaly Management Process shall accept, monitor, track and ensure closure of all anomaly reports written by Project personnel. The anomaly reports take the form of problem/failure reports (PFRs), failure reports (FRs), incident/surpise anomaly (ISA) reports, and discrepancy reports (to the DSN). These reports are the inputs to this process. The outputs are anomaly assignments, anomaly status and change requests.

Anomaly Management Requirements:

(1) Enabling technology shall be built to provide easy access to write anomaly reports, increase throughput and reduce the level of effort required to perform the Anomaly Management task..
(2) The entire flight team shall have access to the anomaly management system for anomaly reporting.
(3) Anomaly Management shall interface with outside organizations (i.e. MGSO and the DSN).

3.1.7.3 CONFIGURATION MANAGEMENT (CM)

The Configuration Management Process shall monitor and track all changes to software, hardware and documentation. The inputs to this process are change requests and the outputs are change authorization, impact assignments and status. A Configuration Management Plan shall be written to outline how configuration management will be handled on MGS.

CM Requirements:

(1) All workstations, flight software, the ground data system and mission system documentation shall be under Configuration Management .
(2) Team Chiefs shall implement configuration management within their own systems.
(3) Enabling technology shall be built to provide easy access to change requests, increase throughput and reduce the level of effort required to perform the CM function.
(4) All members of the flight team shall have access to the electronic Change Management System so they can generate their own change requests and change reports.

3.1.7.4 PROJECT REPORTING

The Project Reporting Process is the process by which information flows from the lowest level of the MGS Project, up to Project Management and to our sponsor. There are different forms by which this information is communicated, namely (1) written reports, (2) verbal communication over the net, and (3) formal reviews and presentations. All are used by the MGS project.

Project Reporting Requirements:

(1) Written information and reports shall be generated electronically to expedite communication. The latest communications technology shall be used to expedite reporting flow and reduce effort where appropriate and cost effective.

(2) Formal reporting to NASA Headquarters shall be provided in a hypertext mark-up language format for World Wide Webb browsers. Project personnel, including those remotely located, and NASA Headquaraters shall have access to these Monthly Management Reports (MMRs) and Project Monthly Reports (PMRs) .

(3) Daily spacecraft status shall be communicated from Lockheed Martin in Denver, Colorado to the Mission Manager at JPL through verbal communication which is recorded (a.k.a. the daily radio show).

3.1.7.5 SYSTEM ADMINISTRATION (SA)

The System Administration process is used to install Ground Data System (GDS) software on workstations and provide workstation/software maintenance.

SA Requirements:

(1) System Administration shall be supplied by the MGSO organization.

(2) When a new GDS delivery is made, system administration shall be performed in a timely manner as required by the GDS.

3.1.7.6 PDB ADMINISTRATION

The PDB Administration shall provide data administration, database administration operations and E-Kernel generation.

PDB Administration Requirements:

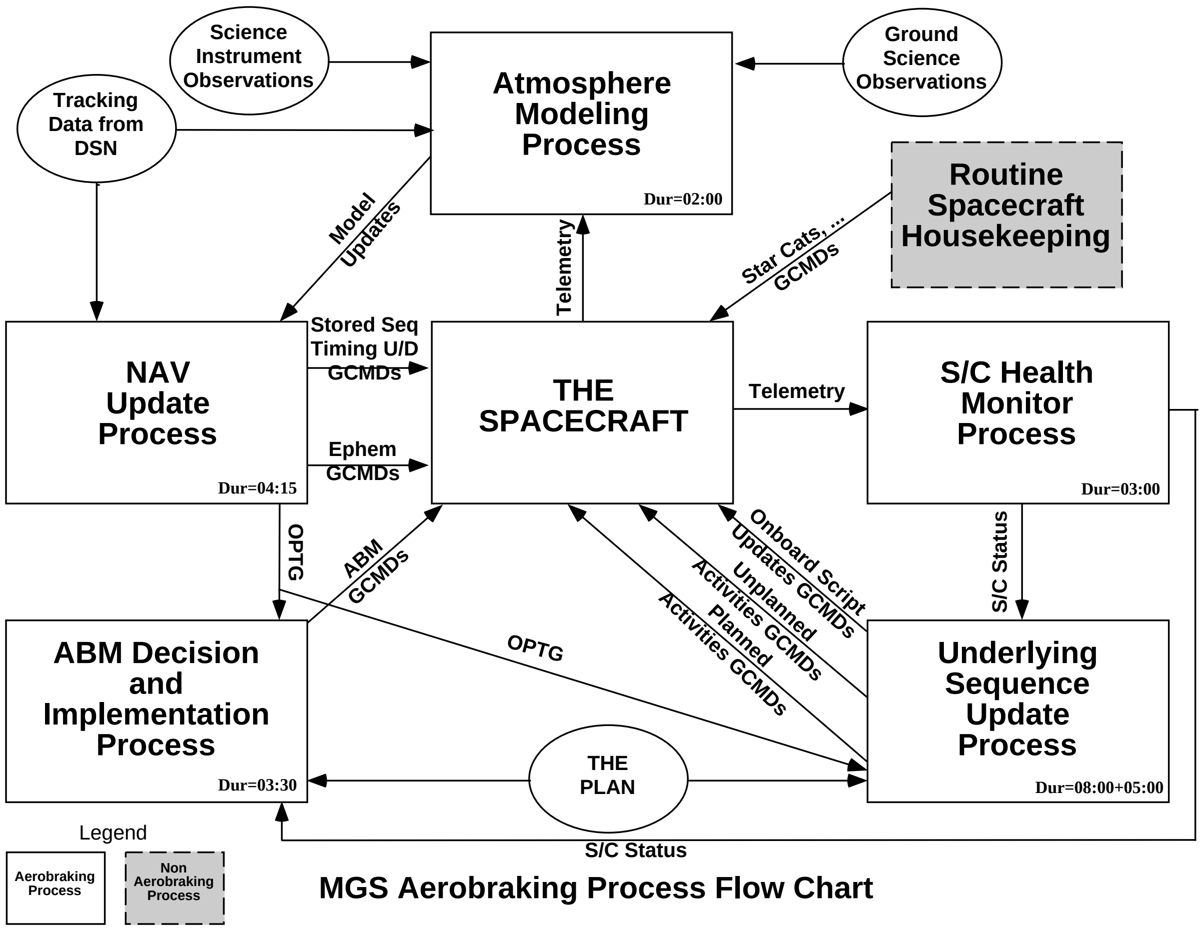
(1) Data Administration shall provide telemetry data accounting and product assurance for the data placed on the PDB.

(2) The E-Kernel generation process shall use the NAIF toolkit. The E-Kernel shall be generated on a weekly basis.

(3) The PDB Administration specific task shall ensure the Project/MGSO interface is operational and the PDB is maintained.

3.1.8 AEROBRAKING PROCESSES

Aerobraking is the method by which the MGS spacecraft uses drag from the Mars atmosphere to reduce the 48 hour eliptical orbit to a circular two hour orbit. Flight team aerobraking processes have been developed to ensure the ground operations can perform the necessary tasks to achieve this goal. Shown below is the Aerobraking Process Map (Figure 3-7). A brief description of each of these aerobraking subprocesses is given below. Details are given in Volume 3.



MGS Aerobraking Process Flow Chart
Figure 3-7

Aerobraking Process Requirements:

(1) The Aerobraking processes shall provide the ground operations with the ability to place the spacecraft in a two hour circular (450 km altitude) 2 p.m. orbit, with minimum use of fuel.

(2) These processes shall be flexible enough to allow the ground operations to meet the aerobraking objectives with a 48 hour orbit and all orbit durations down to two hours.

(3) The Aerobraking processes shall allow the flight team to keep the spacecraft within the corridor.

3.1.8.1 NAV Update Process

The Navigation Update Process is invoked regularly by the flight team to generate the commands required to trigger the onboard aerobraking drag pass script and to update the onboard ephemeris, which is required to maintain proper spacecraft drag attitude through the drag passes. Tracking data is an input to this process and the output is a sequence timing update and updated ephemeris.

3.1.8.2 ABM Decision and Implementation Process

The ABM Decision and Implementation (ABM D&I) Process is the mechanism by which the necessity for an aerobraking trim maneuver (ABM) is determined, selected, and implemented. The ABM D&I Process will be applicable to maneuvers AB2, AB3, AB4 and all ABMs prior to ABX. Based on the availability of a recent OPTG (orbit propagation and timing geometry) file and a current assessment of spacecraft health, the ABM D&I Process begins with an independent assessment of current aerobraking operations by representatives from the MP, NAV and SCT. Within the bounds of operating guidelines defined by the Project, these representatives collectively decide upon the timing and delta-V magnitude of the next ABM maneuver. If this interdisciplinary team decided that an ABM maneuver is necessary (based on the delta-V and magnitude from above), then the SCT will update an SASF containing the request/script trigger command. This interdisciplinary team will also immediately forward its recommendation to the Mission Manager for final approval. If the Mission Manager concurs, then the SASF will be submitted by the SCT to the SEQ’s Express Command (EC) Process for processing.

3.1.8.3 Underlying Sequence Update Process

This process is invoked to update the Aerobraking script or the ABM Master script. It is also used to issue any special commands which may be necessary for operation of the spacecraft and for any commanding necessary to support science data collection.

3.1.8.4 Spacecraft Health Monitor Process

This process is used to monitor the daily health status of the spacecraft. For all practical purposes this Spacecraft Health Monitor Process is the same as the standard Flight System Performance Analysis process used in standard operations. For requirements, refer to Flight the System Performance Analysis process requirements.

3.1.8.5 Atmosphere Modeling Process

This process is used to update the most current model being used for the Mars atmosphere. This process will analyze and review the existing Mars atmospheric model in use by the project, Mars Pathfinder atmospheric data, NAV provided atmospheric density data and SCT thermal and acceleration data to determine a more accurate model for the atmosphere. The inputs to this process are radiometric tracking data, earth calibrations and spacecraft generated supporting files.

SECTION 4.0

MOS ORGANIZATION

This section presents the operations organization that shall be used during mission operations. included is a brief description of how the operations plans and procedures are to be specified and requirements levied on each team.

4.1 DEVELOPMENT ORGANIZATION

The development of the MOS will be performed under the leadership of the MOS Design Team (MOSDT). The team will have representation from each area of mission operations development (spacecraft operations, sequence, navigation, science, etc.). Also Included are spacecraft development and TMOD support services.

4.2 OPERATIONS ORGANIZATION

The flight operations organization structure is shown in Figure 4-1. The MOS shall transition to this organization approximately 6 months before launch. The staffing level of the MGS Mission Operations has been reduced 40% from Mars Observer staffing.

The office of the Mission Manager is responsible for achieving the objectives of the mission. Under the direction of this office, mission operations personnel including institutional support personnel shall perform the functions/processes identified below and delineated in Volume 3.

4.2.1 MISSION OPERATIONS STAFF

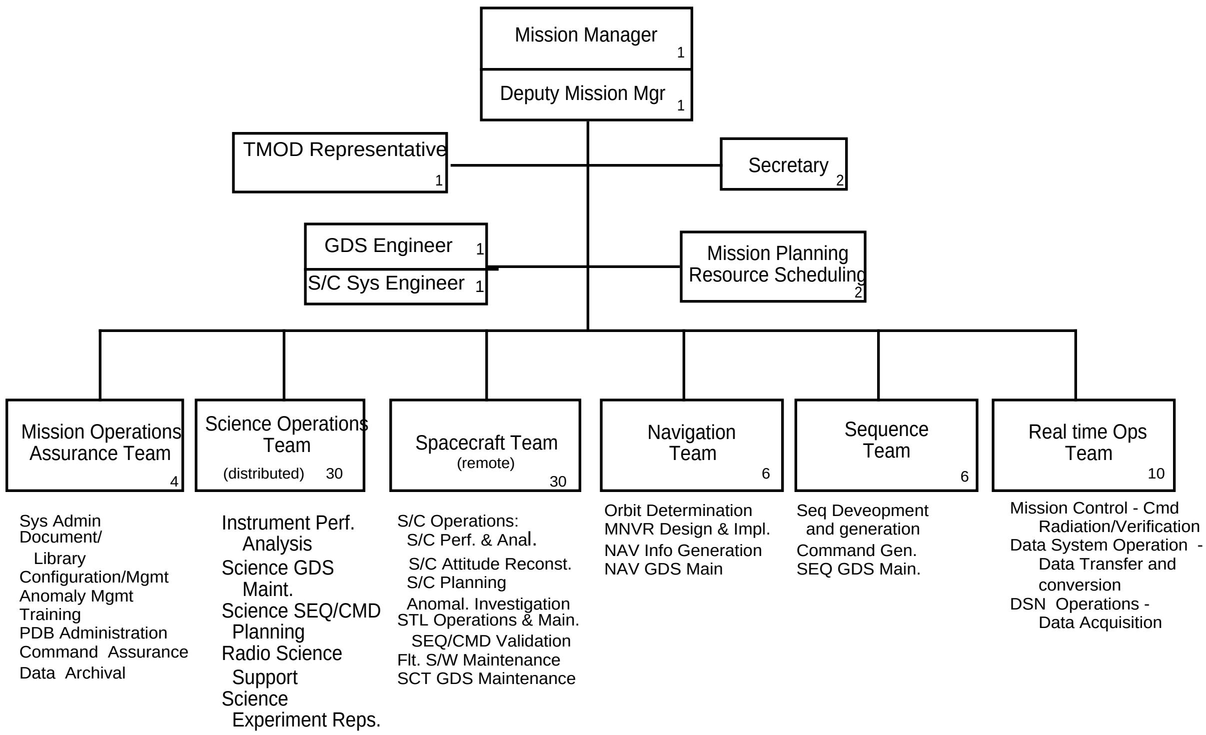
Leadership for MGS Mission Operations shall be provided by the Mission Manager and his deputy. The Mission Manager shall provide the technical direction for MOS development and operations.

The JPL institutional services shall be represented through a TMOD manager assigned to MGS. This manager shall be responsible for ensuring commitments of services and resources to the project by TMOD are fulfilled.

The Ground Data System Engineer shall provide the system engineering necessary to maintain the ground data system distributed through the processes and teams.

The Mission Planner shall provide the detailed plan for the mission and integrate it with the incoming requests. The Resource Scheduler shall provide the long and short term DSN negotiation services to the project and interface on behalf of MGS with the TMOD Resource Allocation Planning (RAP) Process.

Figure 4-1
Mars Surveyor Program
Mission Operations Organization



4.2.2 **MOS FLIGHT TEAMS**

There are six teams which comprise the Mission Operations Organization. These teams are responsible for accomplishing the MOS processes described in Section 3.

4.2.2.1 MISSION OPERATIONS ASSURANCE TEAM

The Mission Operatons Assurance Team shall provide the services for system administration, maintaining documentation, configuration management, command assurance, anomaly management, maintaining facilities, ensuring the flight team is trained, providing administration of the data and project database and generation of the E-Kernel.

4.2.2.2 SCIENCE OPERATIONS TEAM (SOT)

This team is comprised of the engineers and scientists responsible for all aspects of operating the science instruments (including Radio Science). Some of these team members will be located at the investigator’s home institution, although they will have representation at JPL in the form of an Experiment Representative. Through the SOT, the investigative teams shall establish science objectives, plan science observations, evaluate instrument health, and be responsible for the overall operation of the instruments. The team shall produce a conflict free science observation plan based on pre-defined baseline sequences, spacecraft and ground performance information, and project supplied resource inputs.

The following shall be performed by the MOS (for the SOT).

a. Science Operations Planning Computer. A SOPC shall be provided to each of the science investigation teams. Each SOPC shall contain: planning software enabling the team to determine future observation opportunities; command request software enabling those teams having specific instruments to send commands to their instrument; analysis software enabling the team to display science engineering parameters; and communication capabilities for data transfer to and from the PDB.

b. Data Products. Data catalogs, instrument packets, command report logs, spacecraft and ground status and final sequences shall be available within 24 hours after data receipt. Final spacecraft pointing information in SPICE format shall be available within 14 working days of related instrument packet information.

c. Planning Data. Each of the investigation teams shall receive products assisting them in planning observations. The information shall be available at the start of the planning cycle and will include:

   (1) Predicted spacecraft position information,

   (2) Scheduled DSN tracking allocations,

   (3) Planned spacecraft sequence for the next 28 day period, and

   (4) Digital map of Mars.

d. Instrument Commanding. Each of the experiment teams shall have the capability to request non-interactive commands be sent to their respective instrument from their SOPC.

e. Data Monitoring. Instrument related spacecraft engineering data shall be observed and reported to the appropriate experiment team on a daily basis. Anomalies shall be reported by the MOS within the workshift the condition was observed.

f. Support Software. NAIF tools for SPICE handling, C and FORTRAN compilers, local data base, decommutation and display routines, and standard library routines shall be provided to each SOPC.

g. Investigator Equipment Interface. Each SOPC shall have the ability to transfer information to and from an investigative team supplied facility computer.

h. Science Team Communication. An electronic communications media shall be provided to link the investigation teams and the project together. The communications capabilities shall include electronic mail, data file transmissions, visual displays and other communications related functions.

i. Workstation Delivery. The SOPC shall be made available to assist in investigative team ground software checkout, sequence development and project test and training. Specific delivery dates shall be controlled under project schedules.

The following shall be performed by the Science Operations Team.

a. Instrument Health. Instrument health reports shall be provided to the MOS by each responsible investigation team. The reports shall be transferred to the MOS on a periodic basis; daily during the normal work shift and on a negotiated basis for weekends. Instrument anomalies shall be reported within the workshift the condition was observed.

b. Planning Requests. Planning and command requests shall be free of science instrument and observation conflicts with other science teams. Spacecraft stored sequence requests shall be made available to the MOS within 1 week of the start of the planning cycle.

4.2.2.3 SPACECRAFT TEAM (SCT)

The SCT shall be responsible for analysis of spacecraft and ground data to determine performance, predict future performance, develop engineering objectives, and operate the spacecraft through issuance of commands. The team shall be responsible for operating and maintaining the STL including testing of uplink sequences; testing of flight software changes; investigation of flight anomalies; and fault protection support. These processes shall be defined and controlled through a set of operating procedures, including the initiating of spacecraft commands. Assessment of spacecraft performance shall be provided to the other teams within the mission operations organization. Lockheed Martin shall provide the services of the SCT (remotely).

These tasks shall be performed by the SCT with the support of the services of DSN and MGSO.

a. Performance Assessment. System performance shall be determined from spacecraft telemetry and related ground measurements, and shall include evaluation of the telecommunication link for consistency with planned performance. Reports shall be produced for assessing past performance, determining future plans and developing sequence requests.

b. Spacecraft Orientation. Spacecraft orientation with respect to the planet shall be determined from attitude control sensor information and position information from navigation; included shall be the position of the high-gain antenna. The results shall be output in SPICE kernel format.

c. Predict Performance. Spacecraft trends shall be analyzed and operations personnel shall be provided information on expected spacecraft actions.

d. Planning Activity. System conditioning actions and calibrations required to maintain the specified spacecraft performance shall be identified and scheduled in the sequence activities.

e. Sequence Validation. Stored sequences shall be loaded on the Spacecraft Test Lab (STL) for validation. Special events (TCMs for example) shall be run through STL. A subset of interactive commands shall be validated through STL.

f. Anomaly Investigation. Anomaly investigation support shall be provided in the case of an anomaly using the STL as a tool in analysis.

g. Operating and Maintaining STL The operation and maintenance of the Spacecraft Test Lab shall be provided by the SCT.

h. FSW Testing - In the event that updates to Flight Software and/or fault protection are required, the SCT shall determine what changes are needed, provide those updates, and validate their proper implementation through STL.

SCT Performance Requirements:

a. Performance Assessment. Daily Spacecraft summary reports (of significant events) shall be verbal and weekly spacecraft summary reports shall be provided by electronic mail on Monday summarizing information from the previous week.

b. Spacecraft Attitude. Reconstruction of the spacecraft nadir panel orientation shall be within 10 working days of corresponding science telemetry packet data being deposited in the PDB.

c. Planning. Requests for updates to planned engineering sequence activities shall be made within 3 working days of the start of the planning cycle; requests for future engineering sequence activities shall be in accordance with long-term updates.

d. Sequence Validation. Validation shall be performed in accordance with the stored sequence plan (two - three days) . Interactive command validation shall take as little as a few hours to as much as a few days depending upon complexity, but shall meet the requesters need for timeliness.

Support Services provided to the SCT:

Reports from the TMOD (DSN and MGSO) on daily tracking pass activities including telemetry alarms violations, command activities and radio science acquisitions shall be provided.

Analysis Tools:

Standard software support capabilities of TMOD-MGSO (e.g. decommutation, displays, plot packages, data base management system, conversion routines, file compare, etc.) shall be used. Project unique hardware and software augmentation shall be limited to those functions required for the success of the mission.

Workstation Maintenance:

Maintenance of the SCT workstations shall be maintained through contractors provided by the JPL loan pool..

4.2.2.4 NAVIGATION TEAM (NAV)

The Navigation component of the MOS will be responsible for performing the Navigation Analysis Process necessary to put the spacecraft into orbit at Mars and the subsequent maintenance of the orbit. This process includes determining the trajectory and orbit of the spacecraft, determining the maneuvers necessary to achieve the trajectory and orbit, verifying maneuver performance, predicting its future position, and performing processes associated with determining the spacecraft position. The NAV team will also provide other teams (SEQ and SCT) with the necessary Navigation products.

Navigation tasks shall be performed by the project with the support of the services of TMOD (both DSN and MGSO).

a. Maneuver Design and Implementation. Maneuver design and implementation shall be provided to insert the spacecraft into a capture orbit about Mars (trajectory correction maneuver - TCM, Mars orbit insertion - MOI), to provide aerobraking maneuvers to reduce the orbit to a 2 hour period, to raise the orbit if necessary to maintain a circular orbit, and to maintain that orbit about the planet (orbit trim maneuvers - OTM).

b. Orbit Determination and Analysis. During the aerobraking and mapping phases the actual spacecraft position and its future position with respect to the planet shall be determined. The results shall be output in the SPICE kernel format.

Navigation Performance Requirements:

a. Maneuver Frequency. The Navigation Team shall be capable of generating maneuver designs as frequently as every 30 days for TCMs in cruise, every 14 days for OTMs during mapping, and every day for aerobraking maneuvers during the aerobraking phase.

b. Knowledge Position. Knowledge of the actual spacecraft position shall be determined within 10 working days of tracking data receipt to an accuracy of 9 km down track, 5 km cross track and 2 km radial.

c. Predict Position. An estimate of spacecraft position with respect to Mars shall be determined at the start of the mapping planning cycle with updates submitted as needed (during execution) to maintain the 25 km down track, 8 km cross track, 8 km radial accuracies.

d. Gravity Calibration. The determination of the Mars gravity effects on the orbit shall be completed within 30 days following attainment of the gravity data.

e. Maneuver Sequence Updates. Maneuver parameter updates shall be provided to the Sequence Team no later than one week prior to stored sequence start.

d. Navigation Information. The spacecraft ephemeris and orbital event information shall be provided to the Sequence Team six weeks prior to stored sequence start.

Support Services to Navigation:

Reports from the DSN and MGSO on daily tracking pass activities shall be used in support of this activity.

Tools provided by MGSO:

MGSO shall provide a computer environment capable of hosting the navigation analysis programs including those routines required for performing the gravity modeling calibrations.

4.2.2.5 SEQUENCE TEAM (SEQ)

The Sequencing component of the MOS will generate products in the form of spacecraft stored command loads, and non-stored commands (interactive and non-interactive commands) to operate the spacecraft, instruments and ground system. The stored sequence generation process consists of building a stored sequence every 28 days from a mission plan and integrating it with the latest: engineering, navigation and science observation requests; spacecraft and ground performance values; and available DSN tracking periods. The non-stored command generation process is also used by the Sequence Team to generate interactive and non-interactive payload commands.

Tasks performed by the Sequence Team:

a. Planning Information. Provide updated DSN tracking schedules, baseline sequences, spacecraft performance status and orbital predicts to the users.

b. Validate Requests. Constraint check all requests for compliance with flight rules, constraints, and spacecraft and ground capabilities.

c. Integrate Inputs. Combine the spacecraft engineering, navigation, and science sequence requests to form an integrated sequence.

d. Command Generation. The process shall produce the following types of spacecraft commands:

    (1) Stored sequence loads - commands stored in the spacecraft command and data handling computer for subsequent execution.

    (2) Real-time interactive commands including sequence parameter updates, spacecraft computer memory and payload data subsystem memory loads.

    (3) Real-time non-interactive science commands including science instrument parameter and memory loads.

e. Develop Load File. The requests shall be translated into spacecraft command words (bits) and put into appropriate ground system command files. Products (e.g. sequence-of-events) shall be produced to enable ground controllers to monitor the activity process.

Sequence Team Performance Requirements:

a. Planning Information. Planning information shall be provided to users by the start of each planning cycle.

b. Sequence Loads. Stored spacecraft sequences shall be provided to MGSO/DSN (via the PDB) at least 48 hours prior to the sequence being used on-board the spacecraft.

c. Interactive Commands. User request for issuance of a command shall be provided to MGSO/DSN (via the PDB) as follows: Processing of interactive commands (from PDB pickup to STL input file) shall take a minimum of 30 minutes to many hours (depending upon file size and complexity). Validation shall also vary based upon number of commands and complexity. Once validated, the interactive commands shall be placed on the PDB for command radiation. The process from end to end may take from a few hours to a couple of days.

d. Emergency Commands. User request for issuance of a command for an emergency shall be generated and placed on the PDB within 30 minutes of request receipt.

e. Non-interactive Payload Commands. Processing of NIPCs (from PDB pick up of request to issuance of commands shall not exceed 15 minutes per file. The command will be ready for radiation upon completion.

f. Priority. Commands shall have the following priority in being produced; emergency, interactive, stored, non-interactive.

Command Generation Constraints:

a. Time Critical Commands. With the exception of mission critical events, all activities shall be free of time critical real-time commands.

b. Simulation. The Spacecraft Test Lab (STL) shall be used for those activities requiring bit-level validation prior to the command being sent.

4.2.2.6 REAL-TIME OPERATIONS TEAM (RTOT)

The Real-Time Operations Team shall be responsible for Ground System Monitor Control and Configuration and Command Verification processes. The RTOT shall be responsible for building a calibrated MGS activity-specific GDS string from allotted shared ground resources such as antennae, receivers, telemetry subsystems, etc..

The RTOT then uses this equipment and predict data provided by the Project to the Sequence of Events Subsystem (SEGS) to monitor and control each spacecraft session by assessing the End-to-End Information System predict vs. actual differences.

The RTOT shall be comprised of three subteams - the Mission Control, Data System Operations and the DSN Operations. The RTOT Chief will coordinate the activities of these teams. The RTOT shall provide the following processes:

(1) DSN Operations Team (DSNO)

Inputs predicts and committed resources; and outputs Frame Synchronized spacecraft telemetry packets and station data (e.g. MON 5-15, RSC 10-11 etc.).

(2) Data Systems Operations (DSO)

Inputs predicts, S/C telemetry packets and MON 5-15 data; and outputs decommutated, time-ordered, best available data sets.

(3) Mission Control (MC)

Inputs predicts and EEIS information sets and conducts real-time S/C uplink and downlink operations.

The Real-Time Operations Team shall perform the following functions:

(1) DSN Operations (DSNO)

The DSNO shall perform the ground functions associated with establishing and maintaining the S/C - Earth radio frequency link. The DSNO shall obtain and provide tracking data to the navigation team for each tracking pass. The DSNO shall also provide the DSO with science and engineering telemetry.

(2) Data System Operations

The DSOT shall perform all the requisite data transformations and translocations to convert and move transport frames from the DSNO into channelized engineering and monitor data and science instrument packets on the Project Data Base.

The DSOT shall broadcast engineering, monitor and station data (e.g. RSC 10-11) onto the Project Flight LANS.

(3) Mission Control

The MCT shall provide a real-time monitor and first level analysis of the health and status of the spacecraft. Mission Control shall radiate and verify commands transmitted to the spacecraft. The MC shall also provide predicts (SFOS, DSN keyword file and SOE), scripts and data sets for use by the real-time community.

RTOT Performance Requirements:

(1) The DSN Operations

Spacecraft and station data shall be transferred to the DSO as soon as possible taking into account buffer fill, processing and queuing delays.

(a) Telemetry and Monitor - All data in 12 hours following completion of the station track. All data gap fills and station recalls are completed within this period.

(b) Tracking and Radio Science - All data in 24 hours following completion of the station track. For rapid turn-around activities such as maneuvers, the data availability shall be negotiated with the DSNO.

(c) Tracking Pass Reports - Upon completion of the station track.

(2) Data System Operations

The DSO shall deliver the telemetry, tracking, radio science and monitor data to the PDB as quickly as possible taking into account the effects of buffer, processing and queuing delays. Data will be catalogued on the PDB in time order by data type.

(3) Mission Control

(a) Mission Control shall generate the necessary predict products (SOE, SFOS, and DSN keyword file) and update each once/week (or more for critical events).

(b) MC shall prepare command files, radiate them and verify spacecraft receipt according to project timelines, procedures and policies.

(c) MC shall provide real-time monitoring and first level analysis of the health and status of the spacecraft for each DSN pass.

(d) During emergency conditions, commands shall be capable of being transmitted within 10 minutes of receiving project approval assuming the ground is in a command state.

(e) Anomalous conditions observed during the tracking period shall be reported to the Project as delineated in the operating procedures, Volume 4.

(f) In the event of an emergency situation these services shall be ready within 60 minutes.

4.3 PROCEDURES DEVELOPMENT

For each function, a procedure(s) shall be developed and documented in Volume 4. Each procedure shall contain the detailed steps to be followed by the teams.

SECTION 5.0

DATA SYSTEM

This section presents an introduction to the Mission Operations Ground Data System. Detailed requirements shall be found in Volume 2, Ground Data System (GDS).

5.1 GDS OVERVIEW

The GDS is comprised of hardware and software elements from the Project, TMOD, the science investigator facilities, and supporting external organizations.

The GDS subsystems provide the tools the flight operations teams use with appropriate procedures to accomplish mission operations functions. Table 5-1 illustrates the correspondence between the elements and the operations teams.

5.1.1 INTERNAL ELEMENTS

The project has identified six functional elements that are internal to the GDS.

a) Data Acquisition and Command Subsystem (DACS)
This element provides the acquisition and processing of the spacecraft radiometric, open-loop radio science, and telemetry data; command formatting and transmission; ground monitor displays; and simulation.

b) Data Storage and Retrieval Subsystem (DSRS)
This element consists of the Project Data Base and the various tools to handle file storage and retrieval, data access control, cataloging and electronic mail.

c) Engineering Analysis Subsystem (EAS)
This element consists of the set of tools to perform spacecraft analysis and planning. Included are: subsystem performance, telecommunications link analysis, attitude reconstruction, maneuver operations, comparison of predicted values vs. actuals, and maintenance of the spacecraft flight software.

d) Navigation Analysis Subsystemt (NAS)
This element consists of the set of tools to determine spacecraft position, predict the spacecraft trajectory, support maneuver operations, and produce a Mars gravity model.

Table 5-1 Element - Team Relationship

Subsystem/ Teams	DACS	DSRS	EAS	NAS	PSS	SSS
Science						
SIT	no	yes	no	no	yes	yes
SOT	no	yes	no	no	no	yes
RSST	yes	yes	no	no	no	no
Engineering						
SCT*	yes	yes	yes	no	yes	no
NAV	yes	yes	no	yes	no	no
SEQ	no	yes	no	no	yes	no
MP	no	no	no	no	no	no
Operations						
MOA	no	yes	no	no	no	no
RTOT						
DSNO	yes	no	no	no	no	no
DSO	yes	yes	no	no	no	no
MC	yes	yes	no	no	no	no

*includes STL

yes - component(s) of subsystem used by the team

e) Planning and Sequencing Subsystem (PSS)
This element consists of the tools for generation of spacecraft stored sequences, sequence memory maps and commands.

f) Science Support Subsystem (SSS)
This element provides support to the science investigators; it consists of the SOPC, communications tools, packet retrieval and decommutation routines, instrument health monitor and commanding, and NAIF data routines.

5.1.2 EXTERNAL ELEMENTS

Items external to the GDS are treated as system interfaces with the GDS. There are five external elements.

a) Spacecraft Subsystem (SCS)
This element provides the spacecraft bus, payload instruments and ground support equipment interface with the GDS.

b) Launch Vehicle Unique Subsystem (LUS)
This element provides the interface of the GDS with the spacecraft at the Eastern Launch Site.

c) Long Term Data Archiving Subsystem (LAS) - Planetary Data System
This element represents the interface with the Planetary Data System for the repository of the project data.

d) Science Planning and Analysis Subsystem (SPAS)
This element is an extension of the SSE and consists of the functions directly under the cognizance of the science investigators, including science product level 1 through 4 generation.

(e) Verification and Test Subsystem (VTS)
This element consists of the tools to validate sequences and commands, generate corresponding telemetry, and support flight software testing.

5.2 RESPONSIBILITY

Table 5-2 shows the primary responsibility for the hardware and software used in each of the six internal elements.

a) Project - The project shall provide for that software and hardware required beyond the multimission capabilities of TMOD-MGSO to support Mars Global Surveyor. The project shall obtain workstations through TMOD-MGSO.

b) Multimission Ground System Operations - TMOD-MGSO shall provide hardware and software for the project to use and shall provide the basic software for adapting the generic multimission capabilities to MGS.

c) Tracking and Data Acquisition - The TDA through the TMOD- DSN shall provide hardware and software to support the functions associated with communicating with the spacecraft including tracking, radio science, and ground communication links.

d) Science Investigator - The science investigator shall provide the necessary hardware and software required by him/her to operate his/her instrument, complete their science analysis, and or to support planning activities unique to their investigation.

Table 5-2 Hardware and Software Responsibility

Area	DACS	DSRS	EAS	NAS	PSS	SSS
PROJECT						
Hardware	no	no	yes[2]	yes[2]	yes[2]	no
Software	no	no	yes	yes	yes	yes
TMOD-MGSO						
Hardware	yes	yes	yes	yes	yes	yes[1]
Software	yes	yes	no	no	yes	yes
TMOD-DSN						
Hardware	yes	no	no	no	no	yes[1]
Software	yes	no	no	no	no	no
Science						
Hardware	no	no	no	no	no	no
Software	no	no	no	no	no	no

yes[1] - TMOD-DSN provides the circuits (from NASCOM) and TMOD-MGSO provides connectivity to SOPCs

yes[2] - PC's to augment MGSO workstations

5.3 DATA BASE

A project data base shall be established and maintained until end of project. The data base shall be provided and operated through a negotiated agreement with the TMOD-MGSO.

5.3.1 CONTENTS

a. Spacecraft and Ground Measurement Data. Engineering and science instrument telemetry packets, navigation and radio science radiometric measurements, radio science open-loop data, and DSN station generated monitor data.

b. Planning Information. Predicted spacecraft position geometry, sequence and command files, spacecraft and ground timeline activities, and DSN tracking schedules.

c. Operating Reports. Operator logs, command reports, alarm limit violations, ground and spacecraft status.

d. Processed Engineering. Spacecraft engineering and navigation analysis products including the position of the spacecraft in SPICE kernel format. SPICE - Acronym for Spacecraft Ephemeris, Planet/satellite Ephemeris and constants, Instruments, C-pointing matrix, and Event information.

e. Processed Science. Instrument health and reduced data sets.

f. Operational Parameters. Calibration information, parameter alarm limit values, decommutation maps, command constraint files, catalog of data base contents, and science observation request information.

5.3.2 CHARACTERISTICS

a. Security. A security system shall be provided to preserve data integrity and prevent unauthorized access.

b. SFDU Format. All data transfer from or to the data base shall conform to the SFDU standard.

c. PDS Interface. The data base shall have an interface to the Planetary Data System permitting transfer of project information to that data repository.

5.3.3. PERFORMANCE REQUIREMENTS

a. Quantity. The data base shall provide for storage of all data obtained during the mission. The latest 28 days of operational data (nominally estimated to be 14 gigabytes) shall be on-line. The design shall not limit the project to 28 days, i.e. the limit should be by physical size, not time.

b. Access. The data base shall be available 24 hours a day, 7 days a week. Near-term data (i.e. data less than 28 days old) shall be available within 15 minutes of a user query. Older data shall be available within 1 working day.

c. Quality. Data quality shall be preserved throughout the process. The undetected error rate shall not exceed 1 in 10^9 bits.

d. Data Loss. Redundancy shall be provided to prevent unrecoverable data loss from PDB failures. Recovery shall nominally be within 24 hours. For critical periods the time shall be 5 minutes to start of data transfer.

SECTION 6.0

TEST

This section defines the approach to be used to test the capabilities, train operations personnel and demonstrate readiness of the MOS to support the mission. Details of these specifications including the criteria for success will be found in Volumes 6 (Test) and 7 (Training).

6.1 TEST REQUIREMENTS

The tests specified shall be performed by the project. Capabilities provided by TMOD (DSN & MGSO), and other external areas shall be validated by their respective organizations before being integrated into and tested as a component of the Project Ground Data System. Test data sources shall include the use of multimission simulators, real-time and ground recorded spacecraft data, and ground recorded data for regression tests.

6.1.1 GROUND DATA SYSTEM

Elements of the GDS shall first be tested individually and then as an integrated system. During the process all interfaces within and external to the GDS shall be exercised and validated. The system level tests shall be capable of being bench marked and re-run for certification of capabilities after incorporation of changes in the GDS.

It is desirable that all testing be complete prior to the start of formal project training, however, due to the accelerated development, this indeed may not occur.

6.1.2 FLIGHT SEQUENCE VALIDATION TEST

A test shall be performed to demonstrate the ability of the GDS elements to produce a sequence for execution by the spacecraft. This test shall be completed prior to the MOS compatibility test.

6.1.3 MOS COMPATIBILITY TEST

A test shall be performed prior to the End-to-End Test to demonstrate compatibility of the MOS with the spacecraft. MOSC testing shows that commands generated with the GDS software are compatible with the spacecraft; and spacecraft telemetry can be received, processed and monitored by the GDS and MOS analysts. The test shall exercise all modes and configurations of the spacecraft communications and commanding that the ground will use during the mission. Specific mission sequences have been chosen to demonstrate MOS compatibility. They are: MOI, aerobraking, TCMs (TCM#1 and #3), mapping and aerobraking. These stored sequences will be developed by the MOS and tested on STL prior to actual operation on the MGS spacecraft.

6.1.4 END-TO-END TEST

A test shall be performed prior to launch to demonstrate information flow throughout the MOS. The test shall exercise all elements of the GDS starting with the origination of a user request and ending with delivery of the final product. All related ground processing and analysis paths are to be exercised.

6.1.5 POST LAUNCH TESTS

A test shall be performed whenever the project, DSN, or MGSO makes a change to previously delivered and accepted capability. The level of the test shall be determined based on the change.

SECTION 7.0

TRAINING

7.1 TRAINING REQUIREMENTS

Personnel training shall be performed both at the team and system level. All flight team personnel shall be certified as trained prior to the start of operations. New personnel joining MOS after start of formal project training shall receive training within their respective team.

Operations personnel shall be used to the extent permissible to conduct and support testing of the GDS. These personnel shall be used exclusively to perform the End-to-End Test. Training tests shall follow the sequences planned to be used during the mission; contingency plans and anomaly investigation procedures shall be included. Data sources shall include the use of multimission simulators, real-time and ground recorded spacecraft data.

7.1.1 PRE-LAUNCH

A series of training exercises shall be conducted first within the team and then at the system level to demonstrate operations readiness. All mission phases shall be demonstrated. Actual spacecraft data shall be used to the extent practical. A formal Operational Readiness Test (ORT) shall be performed to demonstrate readiness for launch.

7.1.2 CRUISE OPERATIONS

During the cruise phase, training exercises shall be conducted to prepare for the major activities associated with placing the spacecraft into Mars orbit and performing mapping operations. These activities shall be performed starting no later than 60 days prior to MOI to demonstrate readiness for MOI, aerobraking operations, and mapping orbit operations. All functions and elements shall be exercised and validated; emphasis shall be placed on the distributed operations and the supporting data system. The tests shall be completed at least 2 weeks prior to the occurrence of the specific events.

Appendix A to Volume 1

MGS Mission Operations Scenarios

Final

Date: September 1995

Jet Propulsion Laboratory
California Institute of Technology

JPL D-12369

MISSION OPERATIONS SCENARIOS

TABLE OF CONTENTS

TABLE OF CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This document describes mission operations scenarios for all phases of the MGS mission. These mission scenarios are intended to show how the flight team will operate in preparation for launch and in flight.

1.1 Purpose and Scope

The purpose of this document is to show that there is a plan in place to operate the MGS spacecraft in flight, meeting the goals of the project in a cost effective way. Since this mission is essentially the same as the previous Mars Observer mission, many of the fundamental tasks are the same, however, major improvements have been made through re-engineering and enabling technology to increase productivity of the mission operations system. Details of these processes and tools are described in the Mission Operations Specifications, Volumes 2 and 3.

The mission operations scenarios begin in preparation for launch and conclude at the last phase of the mission (the Relay Phase). The flight operations will be performed over a five year period.

1.2 Assumptions

The mission operations system has made the following assumption in designing the mission operations:

a. Most instrument commanding is non-interactive and highly automated.
b. All non-real-time operations work will be confined to a 40 hour work week except during specific high activity periods (such as MOI and aerobraking).
c. The mapping mission is highly repetitive.
d. Cruise and mapping operations will be very similar in operations, using the same procedures and interfaces.
e. The mission can tolerate (as a minimum) 70% data return.
f. Inheritance from MO:
    (1) All GDS hardware will be inherited from MO
    (2) Ground data software - ~ 80% inheritance from MO.
    (3) Spacecraft hardware - ~70%.
    (4) Flight software - ~80%
g. Mars Observer procedures and processes have been re-engineered to maximize efficiency and to minimize staffing requirements.
h. Staff levels will be 60% of Mars Observer operations.
i. The Science Team will be distributed and the Spacecraft Team will be at Lockheed Martin (the spacecraft development site).

j. Mission Operations will use aerobraking techniques to reduce the orbit period from approximately 48 hours to 2 hours.

2. MGS OPERATIONAL FEATURES

2.1 Remote Spacecraft Operations

The Mars Global Surveyor (MGS) Spacecraft Team (SCT) will operate remotely for both nominal and contingency activities. Specifically, the members of the SCT will be located at the Remote Mission Support Area (RMSA) at the Lockheed Martin facility near Denver, Colorado, while the remainder of the flight team (except SOT which is distributed) will be located in the Primary Operations Support Area (POSA) at the Jet Propulsion Laboratory near Pasadena, California. This configuration places demands upon the communication skills and facilities of the flight team members in both locations, but reduces costs and provides for greater key personnel retention. The SCT Chief, the two SCT group leads responsible for Systems and Subsystems, and selected additional senior SCT members will provide a rotating non-continuous presence at JPL throughout the mission for coordination and liaison purposes. The connectivity between Denver and JPL will be essentially identical to the connectivity within JPL.

The Remote MSA will consist of Government Furnished Property (GFP), Automated Data Processing Equipment (ADPE), the GFP Spacecraft Test Laboratory (STL), and Lockheed Martin-provided offices, library, workstation areas and conference areas as specified by the Mars Global Surveyor Denver Mission Support Area Facilities Plan. The interfaces between the Remote MSA and the JPL Advanced Multi-Mission Operations System (AMMOS) will be functionally identical to the interfaces between the POSA in Building 264 at JPL and AMMOS. The interfaces between flight team elements consist of data, voice, and electronic mail/fax, each of which will be discussed in the following sections.

2.1.1 Data Interfaces

The workstations are connected to the MGS Local Area Network (LAN) via a single GFP 448 kbps data line, as shown in Figure 2-1. Telemetry data from the spacecraft will be routed to the RMSA through the JPL Advanced Multi-Mission Operations System (AMMOS) for display on the workstations. The same line will be used for access to the Project Data Base (PDB) which is the central repository for archived telemetry and electronic files. Team-to-team formal data interfacing will be via electronic files stored into and retrieved from the PDB. Selected processed telemetry will also be stored locally on a dedicated Telemetry Delivery Subsystem workstation, to reduce time-critical dependency on the PDB query process. Physical and electronic security will be maintained according to the MGS Security Plan, 542-404.

2.1.2 Voice Interfaces

The voice interfaces will be in three forms. The primary form will be two dedicated full-time GFE voice nets, designated MIC-1 and SCT Cordination, for Press-to-Talk instant communications with other flight team members. The nets will use JPL-supplied digital
VOCA network stations connected to Denver via a dedicated 1.544 Mbps T1 commercial carrier line. MIC-1 is primarily reserved for *inter*team coordination, for example with the Mission Control Team ACEs, the Mission Manager, the Navigation Team, or the Sequence Team. SCT Cordination is primarily reserved for *intra*team coordination, for example between SCT groups or subsystems. Net traffic is subject to formal protocol as defined by JPL.

The second form will be teleconferencing using standard telephone equipment connected to commercial microphone/mixer and amplifier/speaker hardware systems using

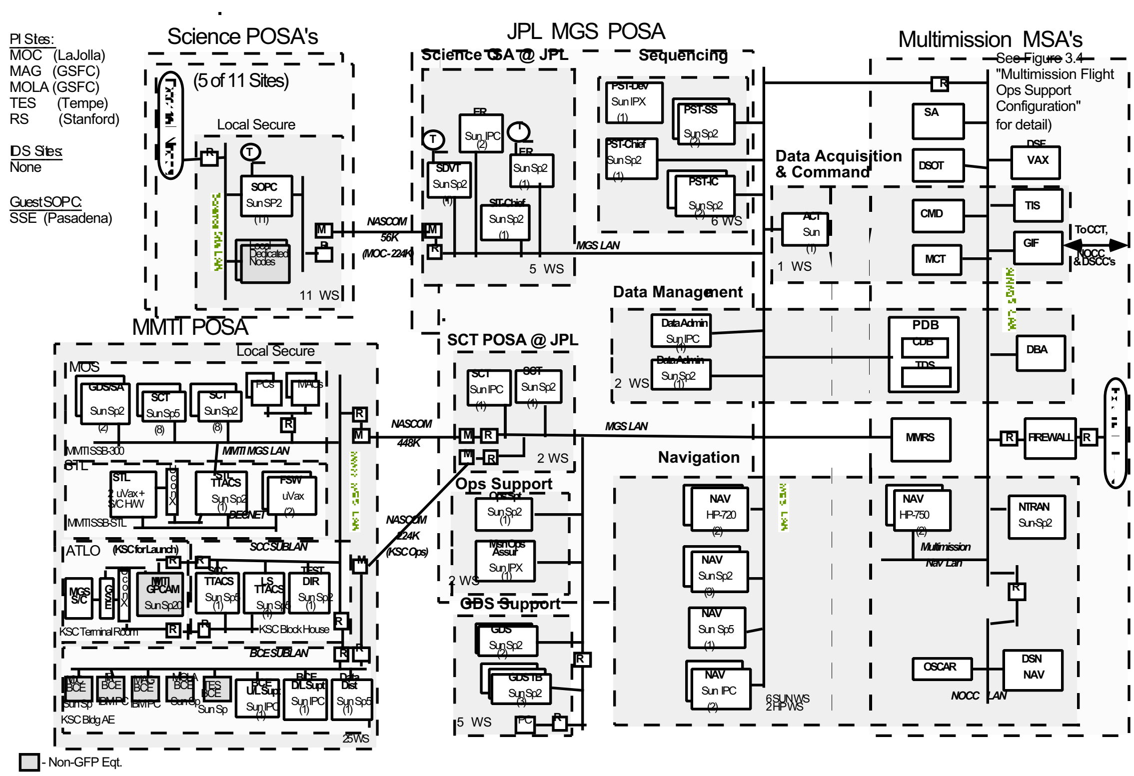


Figure 2-1 Mission Support Local Area Network

distributed multiple microphones in a conference room. The conference room will be dedicated to MGS use for all flight team meetings involving the SCT. The voice teleconferencing system will be used for all meetings which involve interfacing between the SCT and other flight team elements. Video teleconferencing is an option being evaluated for cost/benefit tradeoff. The use of teleconferencing equipment is not subject to a formal protocol, but substantial sensitivity and patience is required for effective use. Side conversations, extraneous noise, and inadequate voice volume or microphone proximity result in inefficiencies, and will be avoided by awareness fostered by use during both development and flight operations test and training.

The third form will be via telephone. The VOCA voice net system will have the capability to connect a Denver user and a JPL user with the 5-digit JPL extension, identical to the connectivity among flight team members in Building 264. The normal 11-digit FTS and commercial connectivity will also exist.

2.1.3 Electronic Mail / Fax

Electronic mail will be used for informal file transfer for such data as status reports and presentation materials. It will also be used for written communications such as memoranda and where multiple recipients are required. The backup mode for e-mail will be via fax, when the e-mail system is unsuitable for whatever reason.

2.2 Distributed Science Operations

Science operations will be accomplished using a distributed system. Each principal investigator and interdiciplinary scientist will communicate with the JPL POSA/Lockheed Martin MSA via a unix workstation which is located at his/her home institution. A System Administrator (SA) will configure each workstation and train the science user.

Science commanding will be submitted and managed by these remotely located science teams, with only a single local Experiment Representative (ER) actually resident at JPL. These remotely located science users will also receive their science data and supporting data products via the Project Database (PDB). Each science investigation will have their own compartment on the PDB for operations transactions.

3.0 TEST OPERATIONS

3.1 GDS Testing

GDS Testing will be conducted as follows:

a) Multimission Subsystem & System Testing

TMOD (MGSO and DSN) will plan and conduct subsystem and system testing of multimission components and capabilities. TMOD testing will take place prior to Project Testing. This will include coordination of MGSO and DSN testing and testing of MGSO/DSN interfaces and end-to-end performance. No explicit project support is planned. For the launch GDS, limited project involvement may occur, but TMOD testing will not depend on any specific level of project support. For MGSO systems, the project will review the results of subsystem testing at the MGSO System Test Review (STR) and monitor the results of system testing.

b) Project-Developed Subsystem Testing

Project-developed subsystems (NAV, SEQ and SPAS) will undergo detailed subsystem testing, as part of the development contract with the implementing organization. This testing will take place prior to Project System Testing. Test plans and reports will be produced. The extent of testing will depend on the amount of deviation from the MO baseline subsystems.

c) Project GDS Prototype Validation & Utilization

As part of the GDS incremental development approach, GDS and MOS personnel will utilize and evaluate phased GDS prototype systems. The first system (Phase 1, ~1/1/95), will be an "MO baseline", upgraded to the latest multimission systems and including connectivity to MOC, STL, FSW Maintenance and SCT skeleton at Lockheed Martin. Subsequent phases will include additional functionality, MGS spacecraft and mission compatibility, and "enabling technologies" for operations cost reduction. Testing and evaluation of prototype systems will be informal. The last prototype phase will take place prior to the start of formal system testing for the L1.0 delivery (~10/15/95).

d) Project System Testing

Project system testing will take place for major GDS deliveries, beginning with L 1.0. Project system testing will involve validation of all MOS system functions and data flows. The testing will be formal (with test plan and reports), will be oriented toward "operations data flows" and will involve both GDS and operations personnel. In general, project system testing will be less exhaustive than that conducted for MO, placing a heavier reliance on the maturity of the MGSO and DSN systems, the completeness of TMOD testing of end-to-end multimission capabilities, and project subsystem testing. A formal GDS Test Readiness Review (GTRR), will be held prior to beginning system testing for L 1.0. will contain 95% of the launch system and will become operational approximately 2/1/96. Compatibility of the GDS with the MGS spacecraft, will be demonstrated during "MOS Compatibility Testing" and "End-to-end Testing" as described below.

3.2 MOS Compatibility Testing

MOS-Spacecraft compatibility (MOSC) testing will involve running key MOS-produced flight sequences (in the form of command loads) on the spacecraft, during spacecraft system test, while the spacecraft is at Lockheed Martin. The command loads will be in the form of "Spacecraft Message Files" (SCMF's) which contain a representation of the complete uplink bit content and timing. The spacecraft ground support equipment (GSE) will use the bit and timing information, to clock the command load into the spacecraft, in a flight-like manner. The DSN command and telemetry systems will not be used during MOSC testing, but will be exercised during GDS testing (described above) and end-to-end testing (described below).

Sequences will be prepared by the MOS (MP, SEQ, SCT, NAV, SOT and RTOT). The same sequences used for sequence validation will also be used for MOSC testing. (See Section 3.3 for identification of sequences.).

All sequences will be validated using MOS tools and the STL, prior to submittal for MOSC testing. Lockheed Martin personnel will be responsible for final validation (and safing) of sequence products (prior to execution on the spacecraft) as well as detailed planning and conducting the MOSC tests.

During MOSC testing digital telemetry data will be routed to the MGSO telemetry system, PDB and flight teams (at JPL, Denver and Science sites).

3.3 Sequence Verification and Validation Scenario

The MGS project will test a series of abbreviated flight sequences to verify that the flight hardware, flight software, MOS and flight team procedures are all consistent and compatible. This testing will occur prior to launch and will involve all elements of the flight and ground systems. The following sequences will be tested during this period.

- The MOI sequence
- A typical Aerobraking sequence
- A Propulsive Maneuver sequence
- The Payload Checkout sequence
- The Mapping Deployment sequence
- A typical Mapping sequence

Each sequence will be built using an accelerated version of the uplink stored sequence development process. The development will begin with the Mission Planners providing the requirements and restrictions (to be followed for each sequence). A Time Ordered Listing (TOL) will be developed, and the formal sequence files will be generated (from SASF to GCMD) by the Sequence Team based upon the TOL. A Flight Team review of the sequence data products will occur and necessary changes will be made. The ATLO/Spacecraft Team will retrieve the test sequence file from the Project Database (PDB) and run it through the Spacecraft Test Lab (STL). After the run is validated, the test sequence will be loaded onboard the real spacecraft memory and allowed to execute to completion. Test data products will be generated and reviewed by the Spacecraft Team for sequence validation. Any errors found will be corrected and documented.

3.4 End-To-End Testing Scenario

The primary objective of the Mars Global Surveyor Test Program is to establish maximum confidence that the Spacecraft will meet its mission objectives. Towards this end, the test program will:

(a) Verify compatibility between the Mars Global Surveyor Spacecraft and other Project systems. They include the Deep Space Network, Ground Data System, Mission Operations System, and the Launch vehicle.
(b) Verify by test that the Spacecraft meets the requirements as specified in the system test requirement document.
(c) Develop a historical data base that will be used for evaluation of mission performance for each major subsystem.
(d) Utilize the database for data "trending", limit checking and to locate, evaluate and correct any potential failure modes.
(e) Verify the ability of the design (Mechanical and Electrical) to withstand the anticipated flight environments by testing in appropriate simulators.

3.4.1 General Data Requirements

Real time, off line and post-test data analysis shall be accomplished in sufficient detail to verify that the test was successful. All data shall be evaluated for any variation from expected or normal operation. Deviations from the expected or any out of limits condition will be evaluated and a Problem/Failure Report (PFR) written.

Data associated with special instrumentation and facilities such as the space chamber or acoustic facility will be processed and evaluated by the respective organization. These organizations shall be responsible for the operation of their facility and related test equipment. They will provide the data acquisition and evaluation tasks and report the results to the ATLO team. This data (plots, strip charts, tapes etc.) shall be saved and filed with the official copy of the respective test procedure.

3.4.2 Real Time Data Analysis

During the conduct of a test, real time analysis shall be performed to verify that the Spacecraft configuration and data are as specified by procedure. While testing is in progress, data will be continuously available for real-time monitoring via the GDS (Ground Data System) and the TTACS (Test Telemetry and Command System) workstation. In addition the GSE (Ground Support Equipment) located in the STC (System Test Complex) will have access to data via direct access and umbilical cables.

In addition to the Ground Data System workstation and displays, the subsystem GSE located in the STC has the capability of monitoring various subsystem functions via direct access or umbilical connections.

3.4.3 Post Test Data Analysis

Post-test analysis shall consist of a detailed evaluation of the test data verifying that no limits were exceeded. Selected telemetry channels may be selected to plot and / or print to obtain critical trend information. The final analysis consists of a detailed review of the processed data and verification that there are no unexplained deviations from a "Base-line" condition that was obtained during previous testing. This process will confirm that proper sequence was followed during the test and that the data obtained can be compared with previous tests and verified to be acceptable.

Trend data shall be accumulated for the Flight System over the duration of the testing activities. Certain measurements that indicate health, efficiency or any other performance indicator will be trended.

Results for those functions for which trending data is being obtained shall be compared against previous results and recorded on trending charts or plots maintained by the affected subsystem. Per the subsystem analyst's request, post-test analysis of the data may require that the Ground Data System playback other supporting data from this or other tests. Comparisons of the playback of this and the previously conducted tests will verify that no related limits have been exceeded during these tests and will substantiate the data trend evaluation.

3.4.4 Test Data Review and Acceptance

Informal incremental data reviews will be held after specific tests have been accomplished. When a consensus by all parties has been reached that the data is acceptable and there are no unresolved anomalies, then the test and data is considered acceptable.

There are also "Pre-Test" data reviews where it is determined that it is acceptable to proceed with the next test phase. Typically these will be:

(a) Initial power turn-on to a subsystem
(b) Major changes in the test configuration such as early vibration, acoustic, solar thermal vacuum, etc.
(c) Tests involving external interfaces such as; handling and transport equipment, propellant loading carts, launch vehicle interfaces etc.

Formal reviews of the test data and ATLO activities will be held at the Flight System Pre-Shipment and the Pre-Launch reviews.

3.5 Operational Readiness Testing

Operational Readiness Tests (ORTs) are tests conducted at the Flight Team level after team training is completed, in the most realistic environment practical. ORTs are given a very high priority and are planned before each critical phase of the mission. Credible simulated anomalies are inserted at key periods during the ORT to provide confidence that contingency planning has been performed, that recovery procedures are in place and that adequate margin in the total MOS process exists to accommodate unexpected events without compromise to the mission plan.

The ORTs, especially those to be conducted during flight operations, are carefully planned to not compromise the safety of the active spacecraft or the objectives of the mission plan; the spacecraft itself is not part of the ORT. Several coordination/planning meetings are scheduled to confirm that all the products, services and personnel necessary for the conduct and evaluation of the ORT are understood and in place. Risks to the on going mission are identified and carefully assessed; activities that pose an unacceptable risk to the mission are replanned or eliminated from the test time line.

ORTs are planned for launch, MOI (including aerobraking), a typical mapping sequence and a typical trajectory change maneuver (TCM). Other flight team test activities may be combined with the scheduled ORTs as resources permit.

During any given ORT, each participating team will utilize procedures, interface agreements and tools that will be used during the actual event or activity. To the maximum extent possible, the personnel that will be on duty during the actual event will also participate in the ORT.

For any given ORT, a script or timeline is constructed based on the time each team has determined it needs to provide its service or produce its product. Allowances are made for not-yet-delivered GDS functionality or required support to the ongoing spacecraft activities.

A typical ORT (for a TCM, for example) would involve the RTOT (DSN Operations and Mission Controllers) , the Navigation Team, the Spacecraft Team, and the Sequence Team. In this case, suitable radiometric data would be generated by DSN Operations (DSNO) using internally accepted procedures. The DSNO would pass an Orbit Data File to the Navigation Team in the format required. The Navigation Team would then generate an orbit determination solution from which the desired maneuver parameters would be derived. The Navigation Team would then deliver a maneuver file to the Spacecraft Team in Denver, Colorado. The Spacecraft Team would conduct the necessary spacecraft subsystem analysis and provide spacecraft executables and other spacecraft configuration requirements to the Sequence Team for the generation of the spacecraft maneuver sequence. Along with other supporting information to properly configure the data system, the command sequence would then be delivered to the Mission Controllers for command radiation through the DSN. While the file would not actually be radiated to the active spacecraft, it would be transmitted into a dummy load. All of these activities would be executed in accordance with approved procedures, including flight team and MOS management reviews and approval. Green card anomalies (simulated anomalies) may be introduced by the training engineer during an ORT.

4.0 PRE LAUNCH/LAUNCH OPERATIONS SCENARIOS

The Mars Global Surveyor spacecraft will launch aboard a McDonnell Douglas Delta II 7925 from Launch Complex 17 (SLC-17) at the Cape Canaveral Air Force Station. The launch period extends from November 5, 1996 to November 25, 1996 with two instantaneous (approximately 1 second) opportunities per day. Project launch operations run from the application of initial downlink spacecraft power (24 hours prior to launch) until the spacecraft initial two-way acquisition approximately 95 minutes after launch. Table 1 shows the Delta II event timeline.

Major activities of the Launch phase include spacecraft preparation for launch, confirmation that all spacecraft subsystems are operational for flight, the launch events themselves, and initial acquisition/checkout.

Event	Time HH:MM:SS.SS	Time (seconds)
Liftoff	00:00:00.0	0.0
Mach 1	00:00:32.1	32.1
Maximum Dynamic Pressure	00:00:49.1	49.1
6 Solid Motors Burnout	00:01:03.1	63.1
3 Solid Motors Ignition	00:01:05.5	65.5
Jettison 3 Solid Motors	00:01:06.0	66.0
Jettison 3 Solid Motors	00:01:07.0	67.0
3 Solid Motors Burnout	00:02:08.8	128.8
Jettison 3 Solid Motors	00:02:11.5	131.5
Main Engine Cutoff (MECO)	00:04:20.7	260.7
Stage I-II Separation	00:04:28.7	268.7
Stage II Ignition	00:04:34.2	274.2
Jettison Fairing	00:04:42.0	282.0
First Cutoff - Stage II (SECO1)	00:09:35.0	575.0
Stage II Restart Ignition	00:39:32.5	2372.5
Second Cutoff - Stage II (SECO 2)	00:41:37.8	2497.8
Fire Spin Rockets	00:42:27.7	2547.7
Stage II-III Separation	00:42:30.7	2550.7
Stage III Ignition - NCS Enable	00:43:07.8	2587.8
Stage III Burnout (TECO)	00:44:34.9	2674.9
Disable NCS	00:50:27.0	3027.7
Initiate Yo-Yo Despin	00:50:27.0	3027.7
Spacecraft Separation	00:50:32.0	3032.7

Table 4-1 Delta II 7925 Launch Event Timeline

4.1 Data Flow

While on the pad, data will flow to the JPL POSA and Lockheed Martin RMSA by the process outline in Figure 2-1. The spacecraft is powered on approximately 24 hours prior to liftoff. Data flows via an umbilical pathway that passes through the Delta II payload fairing (PLF) into the SLC-17 blockhouse where the TTACS workstation is located. The method for shipping data back to the MGS GDS at JPL is to pass the raw data through the TTACS (probably via MIL-71) and have the ecommution/channelization done at the TIS at JPL. Data will then be propagated through the MGS LAN to local workstations, onto the Denver RMSA, and into the project PDB.

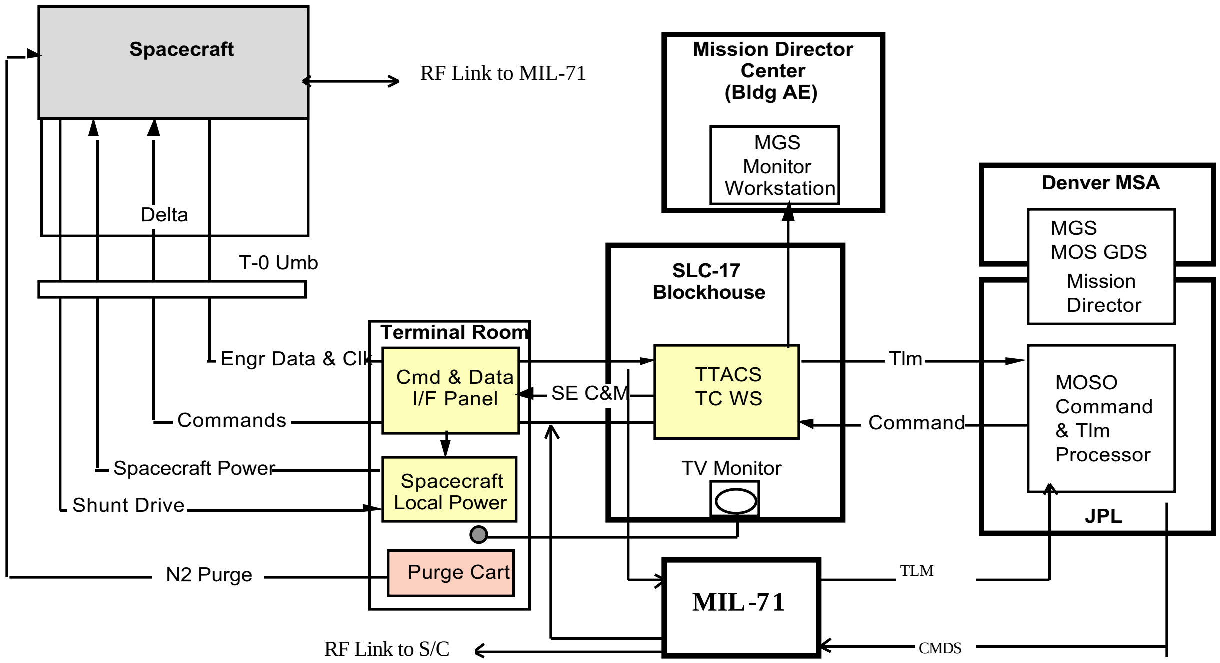


Figure 4-1 S/C to POCA Data Flow

The Delta II does not have a capability to provide spacecraft downlink telemetry to the project following liftoff. Delta and PAM-D telemetry will be downlinked to tracking stations and ARIA aircraft but spacecraft telemetry cannot be downlinked. All post launch spacecraft telemetry will be recorded on Solid State Recorders (SSR) on-board the spacecraft. This data will be replayed following successful acquisition of the spacecraft by the DSN. A separation sequence will allow the spacecraft to operate until acquisition. This sequence is activated by a microswitch triggered upon separation of the spacecraft and PAM-D (third stage).

Spacecraft initial acquisition will occur over the DSN Canberra (DSCC 40) complex approximately 67 minutes after separation. An X-band acquisition aid will be used to locate the spacecraft signal and provide pointing to DSS 45 (34-meter HEF antenna). Upon lock-up of data at DSS 45, it will be transferred to the POSA and RMSA via nominal DSN-GCF-JPL interfaces. Figure 4-2 outlines the post acquisition data flow. Once the spacecraft condition and telecommunication characteristics are analyzed, the DSN will conduct an uplink sweep to provide two way radiometric data and commandability of the spacecraft.

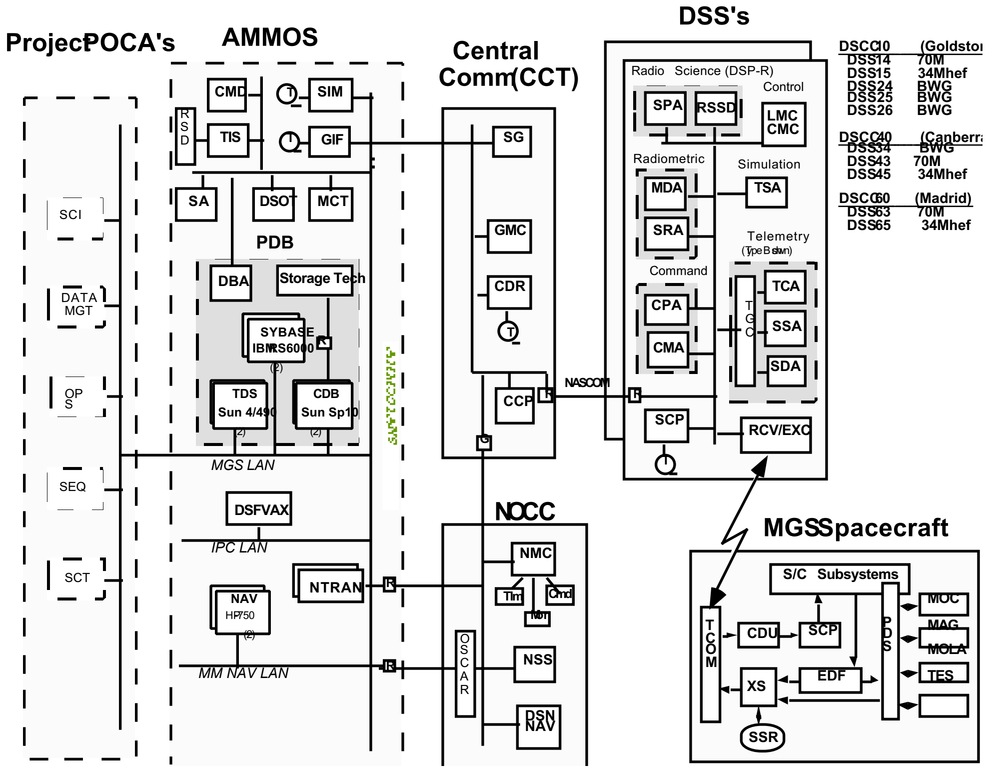


Figure 4-2 Post Acquisition Data Flow

4.2 VOCA Connections

The project MSA will be equipped with VOCA lines necessary to conduct flight operations. This typically includes four VOCA nets: 1) SCT internal net, 2) DSO interface net, 3) TRACK interface net, and 4) a project interface net. The Mission Controller station will be augmented to include tracking and flight nets connecting them with all three DSN complexes and MIL-71.

For launch operations support, nominal voice nets will also include one listen only net for monitoring Delta countdown events, and one duplex line for contact with an MOS interface on the Cape launch team.

4.3 Operations

During launch operations, JPL and Martin personnel will be staffed around the clock starting at spacecraft power on, approximately 24 hours prior to liftoff. Following power-on, spacecraft telemetry is monitored to ensure spacecraft health is as expected. All flight systems are powered and flight software is loaded. The MGS launch sequence is then loaded on-board into spacecraft memory. Command verification and memory readouts can be used to verify proper receipt. The MGS launch sequence is a script of spacecraft time ordered commands that will clock out to configure the spacecraft for launch. Major activities included in the launch sequence are shown in Table 4-2.

Launch Sequence Event	Time (Liftoff = L-00:00:00)
S/C power on	L-24:00:00
SCP's powered and FWS loaded	
EDF Time Set	
SCP set to EDF time	
Enable REDMAN	L-21:00:00
Configure SSR	L-21:00:00
Load Epheremis and validate	L-20:30:00
Disable Safemode	L-19:00:00
JPL-Martim-CCAFS VOCA Comm Check	L-06:00:00
S/C enable plugs installed (mechanical, not sequence activity)	L-05:45:00
MOS "GO" Roll Call	L-04:00:00
DSN Pre-Cal begins (DSS 65,45,15)	L-03:00:00
MOS "GO" Roll Call	L-02:45:00
Enable Reaction wheels	L-01:00:00
Begin SSR recording	L-01:00:00
MOS "GO" Roll Call	L-00:45:00
MOS "GO" Roll Call	L-00:15:00
Enable Safe Mode	L-00:15:00
MOS "GO" Roll Call for Launch	L-00:10:00
MGS to internal power	L-00:05:00
Liftoff	**L-00:00:00**
MGS/PAM Separation	L+00:49:05
Solar Array Deployment	L+00:55:16
Enable momentum control	L+00:56:20
MGS attitude state to DSNISH	L+00:56:27
S/C Mnvr to DSN Acq Attitude	L+01:05:37
RPA beam on/ X-band AOS	L+01:05:38
Uplink C1 sequence	L+36:00:00

Table 4-2 Launch Sequence Activities

(NOTE: All times are approximate)

4.3.1 Uplink Activities

The launch sequence, flight software, and all pre-launch commands reside aboard the spacecraft at launch. No ground commands will be sent to the spacecraft during the launch sequence. The first cruise sequence (C1) is pre-canned and updated quickly post launch with the specific launch date and time.

This updating is done during the launch period and radiated to the spacecraft within approximately 36 hours after launch.

4.3.2 Downlink Activities

Primary responsibility for monitoring spacecraft subsystem health lies with Lockheed Martin Spacecraft Team (SCT) members located at the launch site in Florida and the Denver MSA facility. General system level monitoring and real time analysis will be conducted by the JPL Mission Control (MC). All pre-launch sequence events will be confirmed as executing properly. System/Subsystem Analysts will be queried by MCs for subsystem status at several points during the launch phase. This status will be passed on to MGS MOS management for incorporation into the MOS decision on launch go/no go.

During the Delta II ascent phase, there is no available spacecraft telemetry being down-linked. MOS downlink activities are relegated to observer status of Delta II flight events.

4.3.3 Management

Management's role during launch operations is to stay apprised of the spacecraft and MOS preparedness for the upcoming launch. Spacecraft subsystems will be polled (by MC) for their status during the launch countdown. Based on these polls, MOS management will declare the flight team either go or no go for launch. The MOS Mission Manager, located at JPL, will report MOS launch status to the Project Manager (located at the cape) at several points during the countdown. The Project manager will incorporate this information into the Project status for continuing launch operations. This status is reported to the Launch director twice during the Delta countdown, with the last poll approximately 5 minutes prior to launch.

4.3.4. Mission Planning and Sequence

Although Lockheed Martin is responsible for the launch sequence, Mission Planning and the Sequence Team will participate in the development of said sequence using the standard stored sequence process. Mission Planning with generate the time-ordered-listing (based upon the most current version of the launch sequence from Lockheed Martin) and the Spacecraft Team will update and modify this sequence to reflect the final launch commands, timing and configuration. The Sequence Team will generate the necessary files to build, verify and validate the spacecraft command file.

Mission Planning and the Sequence Team are involved in anomaly support during launch operations. A major portion of their work is involved with the preparation and update of the C1 sequence that begins at L+48 hours. The pre-canned C1 cruise sequence must be updated to reflect the actual time of launch vs. planned time. This work can only be done post launch and must be complete prior to the transmission at L+36 hours.

Upon initial spacecraft acquisition the MOS will again assess spacecraft health. Mission Control will request any necessary changes to the standard DSN configuration to increase link performance. Verification of all script events will be performed. If emergency conditions exist, proper procedures will be implemented.

4.3.5 Navigation

The Navigation team has created a default planned trajectory file prior to launch that is passed on to the DSN for tracking purposes. Once the Delta has left the pad, the Delta POCC will pass ascent trajectory information to the project and DSN navigation team. Updates to station pointing predicts are made with these inputs. Upon initial acquisition, the DSN will obtain a 2 way coherent link with the spacecraft as soon as possible. Range and radiometric data will be passed to the project Navigation Team for further refinement of the spacecraft trajectory.

4.4 DSN Acquisition Strategy

The DSN has responsibility for the overall initial acquisition strategy of the MGS spacecraft, and the execution of the initial acquisition of the X-band downlink to establish a 2-way command capability. The DSN will also provide sufficient radiometric data to accurately determine spacecraft location and path.

Following the launch of the Mars Global Surveyor spacecraft from the Cape Canaveral Air Force Station and the execution of key launch phase events, the DSN will proceed to establish communications with the spacecraft. (SeeTable 4-2 for Launch Sequence Activities.)

The post separation spacecraft attitude with the low gain antenna (LGA) at a near constant 90 degree offset from the Earth/Probe/Sun orientation line, as depicted in Figure 4-3, is the spacecraft attitude which will provide the most favorable conditions for DSN initial downlink acquisition. The 90 degree offset LGA aspect angle will provide a constant, but slightly lower then desired signal. Great emphasis is placed on the “constant” nature of the downlink signal during this critical phase of the launch sequence.

Following spacecraft separation from the launch vehicle, spin stabilization, and pre-programmed turn-on of the MGS spacecraft X-band transmitter, the Initial Acquisition phase begins.

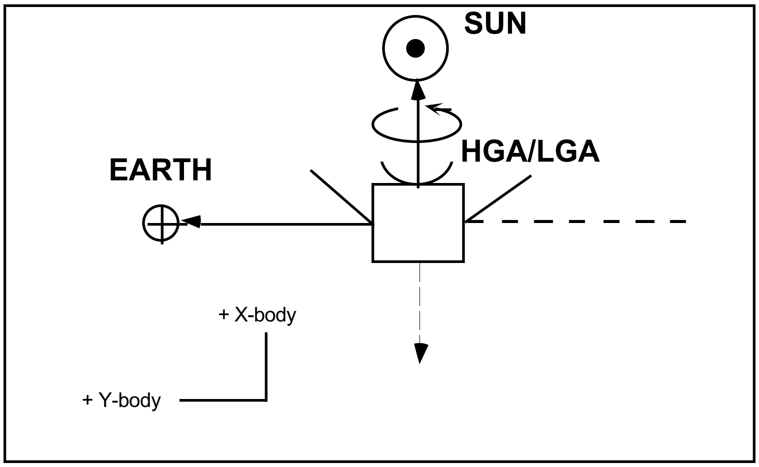


Figure 4-3 MGS Spacecraft Initial Acquisition Orientation

Initial DSN view of the MGS spacecraft will occur over the Canberra Australia Complex.
Two (2) DSN stations will be utilized to acquire the spacecraft signal and will operate in the following way:

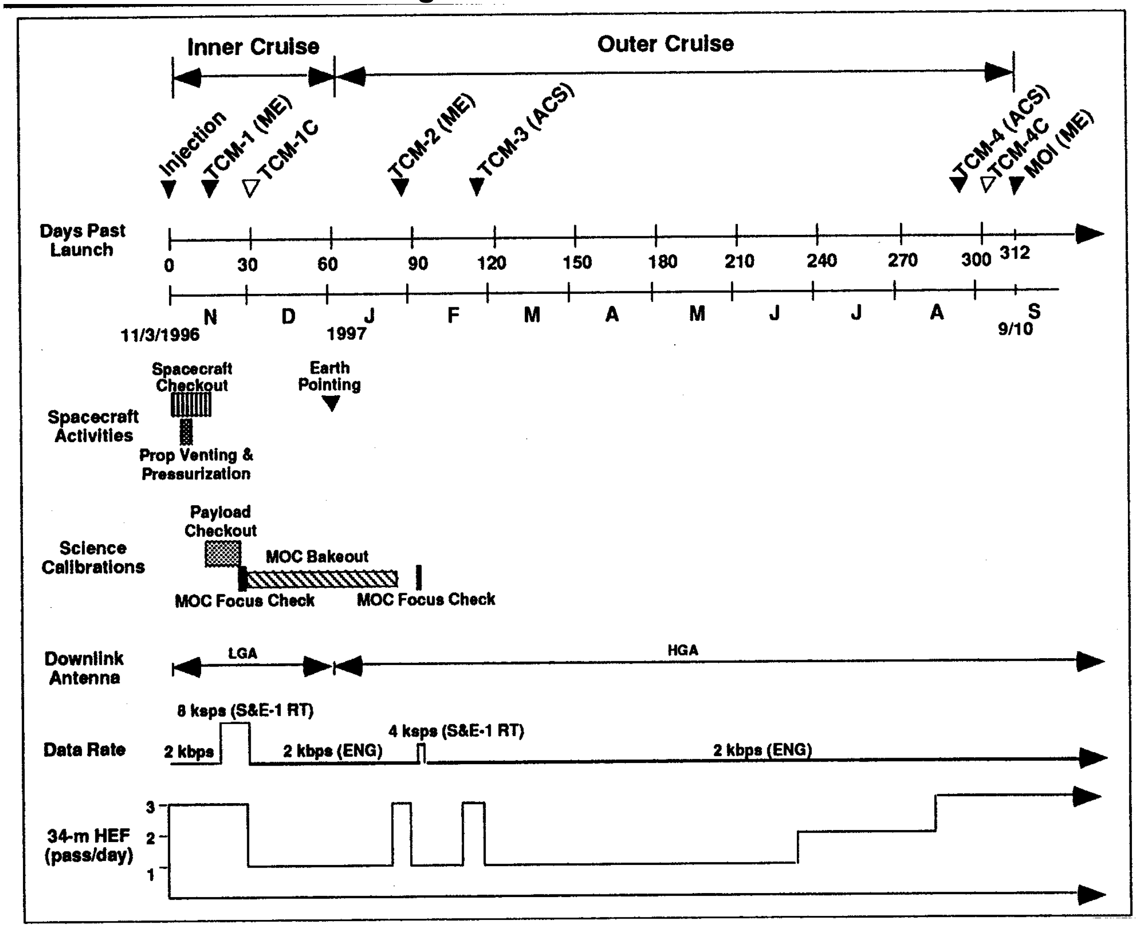
> DSS-46 (26M) utilizing its X-band Acquisition Aid antenna to obtain initial antenna pointing and receiver “lock” status. Antenna angles and receiver frequencies are quickly passed to DSS-45 (34M HEF).
>
> DSS-45 (34M HEF) will utilize antenna pointing angle and receiver frequencies as predicted and updated by DSS-46 to acquire the spacecraft downlink. DSS-45 will then acquire the spacecraft downlink, process radiometric data, and proceed to establish an uplink to the spacecraft. Once 2-way communications are established, the command capability is opened and ranging is initiated.

The spacecraft will be pre-programmed to execute a “Star Map” maneuver at approximately L+57 minutes, at which time the spacecraft downlink will not be available. At the completion of the “Star Map” procedure, the spacecraft will complete its re-orientation, LGA pointing back to Earth, and allow re-acquisition and establishment of 2-way communications.

5.0 MGS CRUISE OPERATIONS SCENARIO

The Cruise phase (10 months in duration) is characterized by a minimal amount of spacecraft activity with the primary focus on trajectory correction maneuvers, spacecraft and payload checkout, and test and training for encounter readiness. (See Figure 5-1 for Cruise Timeline and Events.)

Figure 5-1   MGS Cruise Timeline



Legend:	▼	Primary TCM planned
	▽	Backup TCM opportunity

Mission Events:	Launch: 11/5/96 - 11/25/96
TCM#1	11/18/96 (Launch Dependent)
TCM#2	1/27/97
TCM#3	2/27/97
TCM#4	8/21/97
Orbit Insertion	9/21/97
Aerobraking	9/28/97 - 1/8/98
Gravity Cal (GC)	1/25/98
Mars Mapping	2/13/98 - 1/2000
Relay Operations	1/2000 - 1/2003

Approximately 36 hours after launch the first cruise sequence will be loaded. The first and all subsequent cruise loads will be stored in the spacecraft memory and will in length between 13 and 35 days (allowing TCMs to always be at the start of the load). The ability to send real-time commands during cruise is a capability operations will also provide and there are processes in place to support this activity.

For the first 30 days the spacecraft will be monitored 24 hours per day by the DSN using 34 meter stations. After this period, coverage will drop to eight passes (approximately 10 hours each) per week until preparation for MOI.

Cruise science will be minimal, but not entirely non-existent. The current plan provides for limited imaging during Mars approach. Instruments will perform standard calibrations and checkouts prior to MOI, and some of this data may have scientific value.

Test and training for cruise will occur prior to launch. During cruise the flight team will train for Mars Orbit Insertion and Mapping through operational readiness tests (ORTs) scheduled approximately three months prior to MOI.

Ground software required to generate sequences and commands for cruise will be in place prior to launch. Some software features required for encounter will not be ready prior to cruise, so there will be an encounter software delivery approximately four months after launch - giving the flight team months to make any necessary changes and give their validation. Post launch the ground data system maintenance is supported by each of the individual teams.

5.1 Uplink Operations

Stored cruise sequences take 30 work days to develop. The development is split into two three week phases (each with 15 work days). The first three weeks is devoted to mission planning, afterwhich there is a hand-off to the Sequence Team where the sequence is developed and constraint checked. Validation is performed using the Spacecraft Test Lab at Lockheed Martin in Denver. The Project Database is used as the repository for file hand-offs. Figure 5-2 shows how the development process is staged using two Sequence sub-teams. The Sequence Team uses one Sequence Integration Engineer (SIE) to develop each stored sequence and one for real-time commanding . The ratio between stored sequence development (this includes mission planning) and execution is 3:2.

During the sequence planning phase, the Mission Plan is used as the baseline to lay out the load. The sequence is integrated through negotiation with the support of Navigation, Spacecraft, Science, and DSN representatives. This is all done at JPL with the MGS mission planner leading the task. During the second phase, the stored sequence is developed by the Sequence Team and validated (by the SCT). This phase ends with the generation of the Command Packet File (CMDPKF) by the Mission Control Team, which transfers it to the DSN for transmission to the MGS spacecraft. See Figure 5-3 for details of the the stored sequence process.

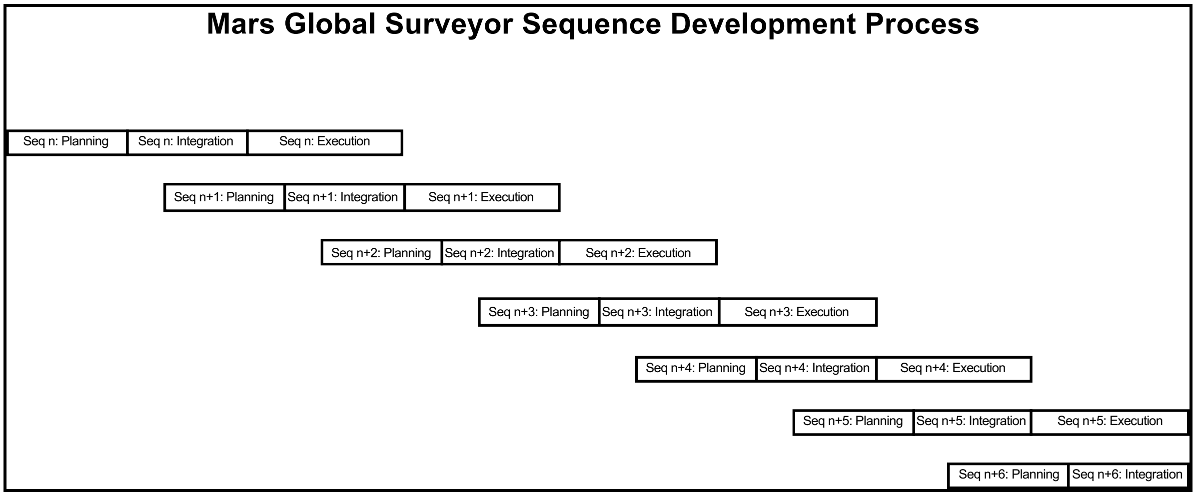


Figure 5-2 MGS Sequence Development Strategy

Maneuvers will be sequenced at the start of a sequence load so as to allow incorporation of the most recent navigation data information into the maneuver. This strategy also allows for solid DSN coverage to monitor the event.

Cruise activities will be based upon the Mission Sequence Plan, which is in accordance with the Mission Requirements and planned staffing levels. Any changes to the Mission Sequence Plan must be approved by the Mission Manager via the Change Board.

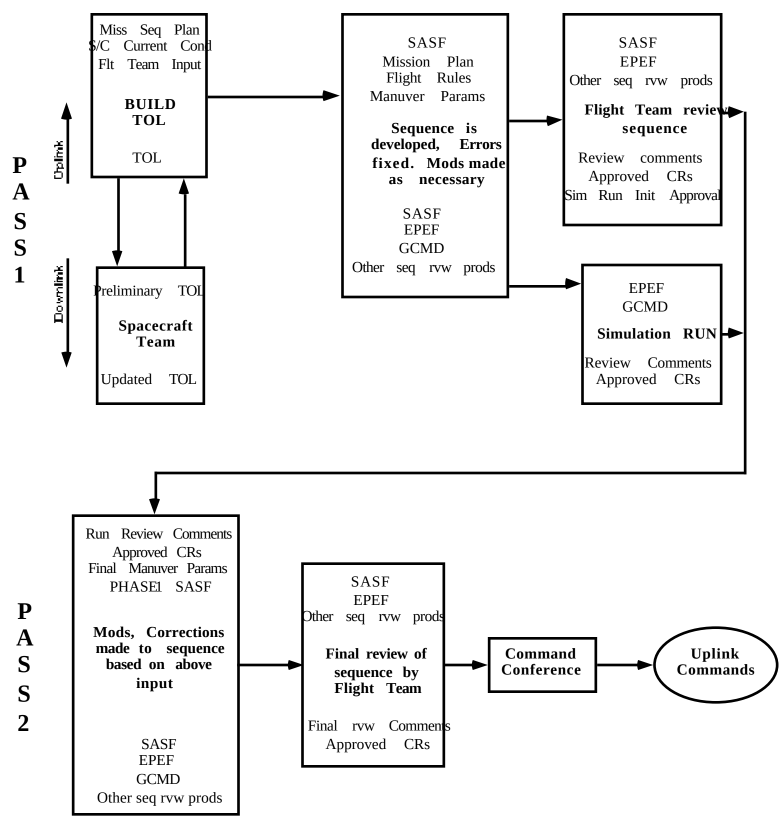


Figure 5-3 Stored Sequence

The Uplink operations also provides the capability to send non-stored commands (also called real-time commands), of which there are two types: interactive and non-interactive. Sending these real-time commands will be accommodated throughout the mission beginning with the first cruise load. The process of building and sending these commands to the spacecraft is shown in Figure 5-4. All non-stored commands can be requested through the proper port any time during the 5 day work week, but transmission to the spacecraft will be based upon available DSN coverage and rigor required for command validation. For non-interactive payload commands the process is extremely fast because these commands require little validation and their processing is heavily automated. In the case of spacecraft interactive non-stored commands, much care must be exercised to avoid damage to or loss of the spacecraft due to miscommanding. Therefore, much rigor is applied to validate these types of commands.

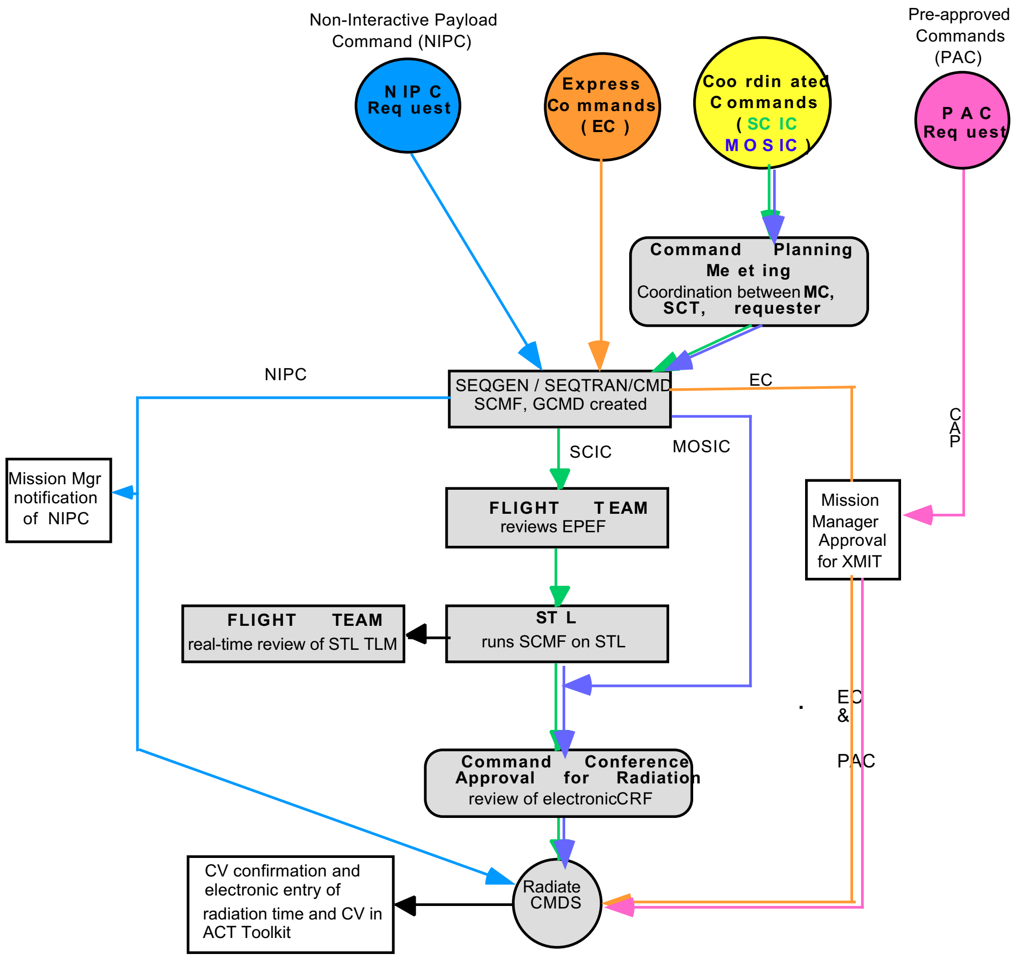


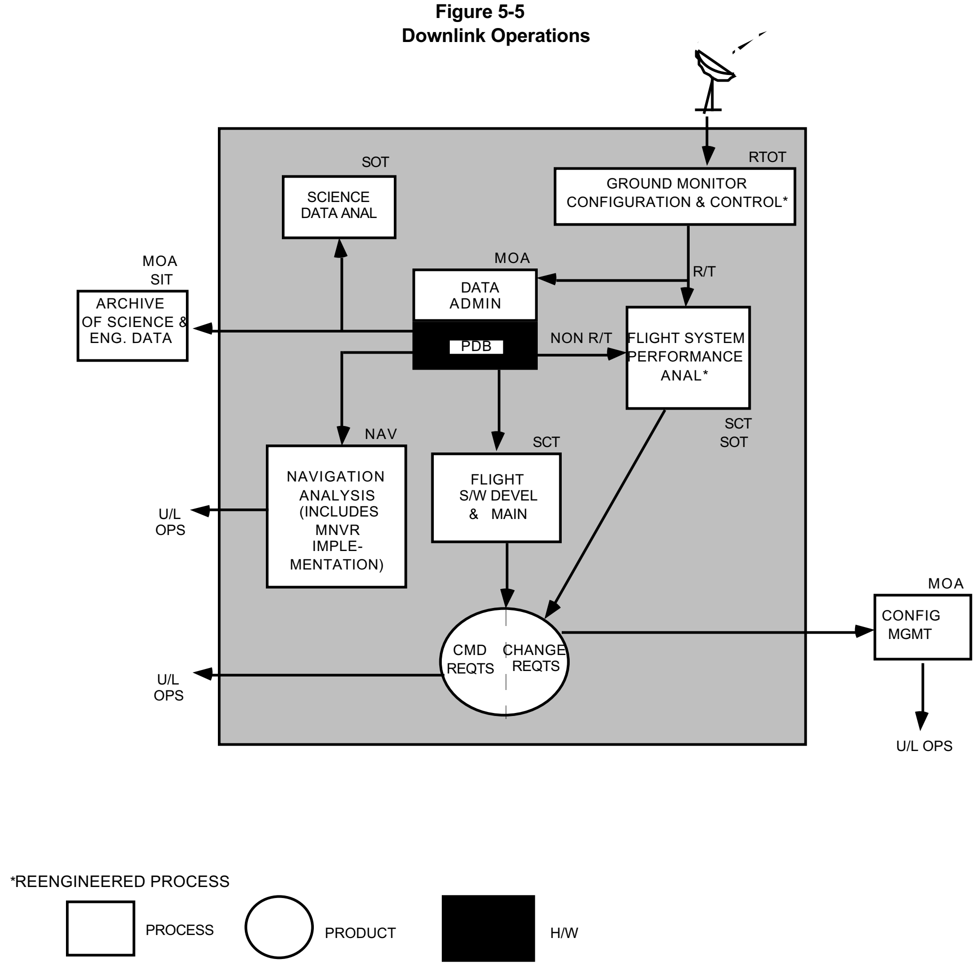
Figure 5-4 Non-Stored Commanding Process

5.2 Downlink Operations

Downlink operations (Figure 5-5) will process spacecraft telemetry, radiometric and monitor data which will be routinely acquired during the one 10 hour pass per day. Normally, Mission Control will monitor performance of the spacecraft and ground data system whenever the spacecraft is being tracked and will provide the initial response to anomalies as defined by project procedures. MC will also provide command verification in real-time when real-time engineering data is available. The Spacecraft Team (SCT) in Denver will be provided with broadcast engineering data whenever it is available.

All stream data will be placed into the Project Data Base (PDB) typically within a few minutes of receipt by the DSN station. (The requirement is that the data must be accessible by query within 24 hours of spacecraft transmission.) Engineering data from the PDB will be used by the SCT to assess performance of the spacecraft, predict trends, design and implement propulsive maneuvers, identify potential flight software modifications and resolve anomalies. That data also becomes the basis for the models and constraints used during sequence generation.

Figure 5-5
Downlink Operations



The science data, in packet form, will be retained in the PDB and sent to the respective science investigation team, when requested (queried). The data will then be processed at the PI's institution to extract the science information. That data will later be archived to the Planetary Data System by the PI. All data on the PDB will be backed up daily.

A daily verbal spacecraft report will be given to the mission manager from the Spacecraft Team in Denver. The conversation will be interactive and recorded. Weekly written spacecraft activity and health summaries will be provided by the SCT by electronic mail. Monthly PMR reports and public information office summaries (on MGS health, status and upcoming events) will be placed in on the World Wide Webb.

6.0 MOI OPERATIONS

Mars orbit insertion (MOI) is the most critical activity of the mission outside of launch. To perform a successful MOI maneuver the entire MOS organization must plan, develop and execute the MOI sequence, the sequences immediately preceding and following MOI, staff the real-time operations and be prepared to implement the approved strategies for contingency response and fault protection.

The MOI activities can be broken up into four operational support phases. Phase 1 will be pre-TCM-4 to develop the sequences surrounding and including the MOI maneuver. The sequences will be created with a back-up MOI maneuver based on the pre-TCM-4 trajectory solution and include the commands and activities to support the planned software fault protection updates unique to this mission activity. Operational Readiness Tests (ORTs) will be held in preparation for this phase. Phase 2 is the period between TCM-4 and the actual MOI maneuver where the TCM-4 maneuver and trajectory are reconstructed for the actual MOI maneuver sequence generation with the final MOI maneuver parameters. This phase also includes the real time updates to the fault protection, such as command loss timer update strategy, contingency and SAFE mode disabling, etc. Phase 3 is the actual execution of the MOI sequence which includes the real time monitoring support of the SCT and MC, the management support from the project, as well as the support from the various MOS support groups, eg. SEQ Team, system administration, NAV Team, etc. Finally, Phase 4 includes the assessment and reconstruction of the MOI maneuver to verify a successful orbit insertion and to provide the Mars orbit assessment to start the aerobraking transition to the MGS mapping orbit.

Throughout this period project, TMOD (MGSO and DSN) facilities, hardware and software configuration will be frozen for the MOI activities.

In preparation for MOI and the activities post MOI, an Encounter Readiness Review will be held.

6.1 Phase 1: MOI Sequence Planning and Development

Critical operations supporting the execution of MOI actually begins prior to TCM-4 with the development of a back-up MOI sequence. The back-up MOI sequence is developed for a nominal orbit insertion aim point determined based on pre-TCM-4 trajectory determination with assumed nominal TCM-4 execution errors. Sequences during this period, in addition to having the correct maneuver design, must incorporate an optimum strategy for maintaining proper energy balance, power profiles and telecommunication links. The sequences will be developed to include the implementation of the fault protection strategies developed for the MOI phase. These strategies have yet to be defined, but should include times to disable contingency and safe modes, command loss timer update, the redundant management fault protection, power energy balance and maintenance of telecommunication links through the maneuver strategies. The overall intent of the fault protection strategy is such that the autonomous response of the system fault protection will not do anything that would prevent the execution of the MOI maneuver or would not allow sufficient time for the ground operations to respond in a manner which would allow for the execution of the MOI maneuver. It should be clear from the previous statement that the design and response of the on board stored fault protection algorithms must be fully coordinated and consistent with the ground operations capabilities and response times.

Around TCM-4 DSN coverage will be scheduled around the clock to facilitate the performance assessment and response to critical spacecraft events. This round the clock coverage should continue through to the acquisition of the mapping orbit following the aerobraking orbit transition phase.

6.2 Phase 2: MOI Maneuver Update and Pre-MOI Ops Preparations

Post TCM-4 the NAV Team will perform the trajectory reconstruction and provide an updated MOI maneuver profile file to the SCT. The SCT will redeliver the MOI sequence SASF for re-uplinking the MOI sequence about MOI-4 days. The fault protection state of the spacecraft will be maintained per the strategy and timeline leading up to MOI and all non-essential spacecraft and operational activities will be curtailed. Operational staffing plans will be finalized and briefings will be held to cover the operations plans between MOI- 4 days and MOI+2 days.

6.3 Phase 3: MOI Sequence Execution

The execution of the MOI sequence and maneuver shall be fully staffed by the SCT, RTOT, project management, NAV Team, and SEQ Team as well as any other MOS support organization. Full representation of the spacecraft subsystems shall be on line through the critical maneuver events. Complete and validated contingency plans associated with MOI will be at the MC and SCT consoles with proper instruction and authorization for their use as needed. Predicts for Telecom, temperature and power predicts and other key spacecraft engineering measurements and status parameters will be at the appropriate subsystem and mission controller consoles to aid in the tracking of the MOI events. Detailed operational timelines shall also be distributed throughout the MOS.

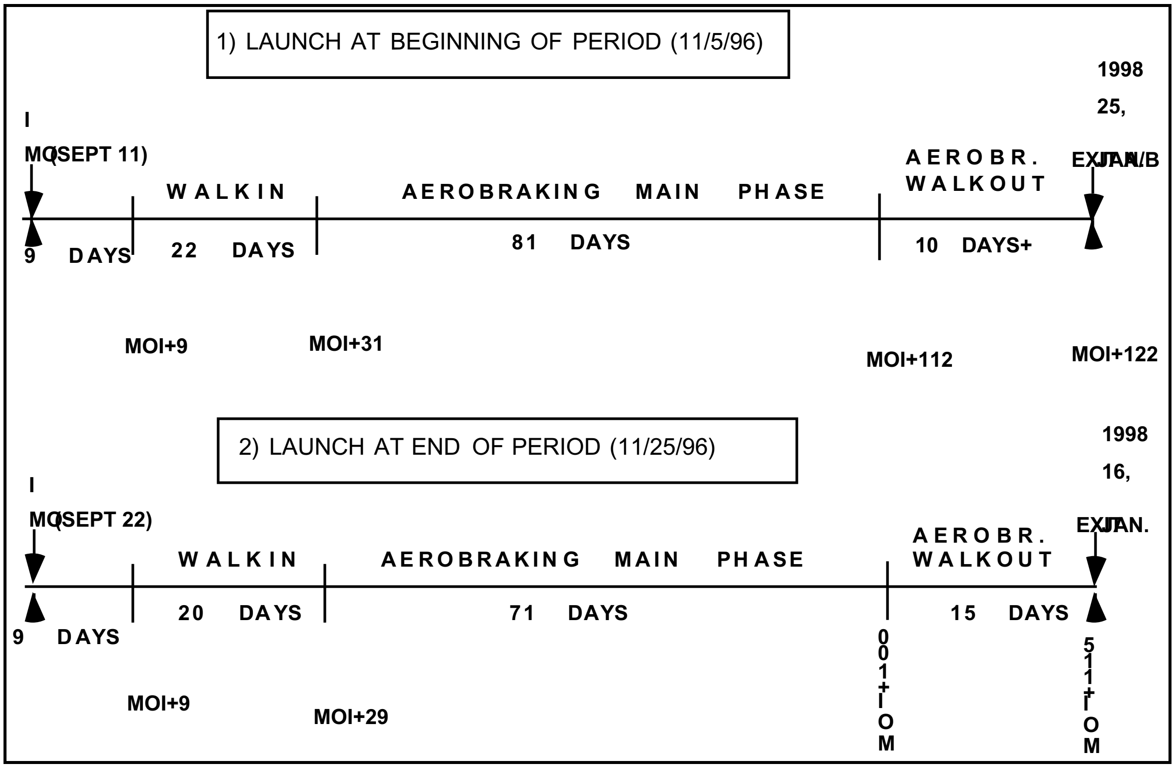
6.4 Phase 4: Post MOI Performance Evaluation and Orbit Determination

This phase calls for a quick assessment of the performance of the MOI burn from the SCT and NAV teams. The assessment shall include: (1) affirmation that the spacecraft has achieved a successful orbit insertion, (2) that it has not experienced any mission threatening anomalies, and (3) that the orbit obtained is in accordance with the upcoming aerobraking maneuver strategy. The SCT and NAV teams will evaluate the post maneuver spacecraft and navigational data sets and present their preliminary assessments within 24 hours of the re-acquisition of spacecraft engineering telemetry. Any anomalous behavior shall be reported immediately by the observing analyst or controller over the voice nets to MC, the SCT Chief and the Mission Manager. Subsequent actions will then be driven by the contingency plans and procedures documented in the Mission Operations Specification documents.

7.0 AEROBRAKING OPERATIONS

The MGS mission will use aerobraking to remove about 1200 m/s of Delta-V at periapsis during the 4 months between Mars Orbit Insertion (MOI) and the attainment of the Mapping Orbit. Aerobraking is spread over 4 months to keep the peak aerodynamic heating rate to an acceptably low level. The 4 month interval is a result of the 2 pm requirement for the mapping orbit and puts a loose upper bound on the capture orbit period. Aerobraking is broken up onto three phases - the walkin, main phase and walkout (shown in Figure 7-1 below.)

Figure 7-1 AEROBRAKING TIMELINE



Aerobraking phases:

1) Walkin - Acquire Atmosphere Densit, Acclimate Spacecraft
2) Mainphase - Perform Major Portion of Aerobraking Delta-V
3) Walkout - Bias Periapsis Upward to Reduce Heating, Increase Orbit Decay Times

The flight team responsibilities during aerobraking include spacecraft commanding (through use of stored commands and real-time commands) to perform the required orbit events, navigation orbit determination and atmospheric modeling, and routine spacecraft health monitoring. Processes have been developed to ensure the flight team can perform these tasks within the resouces.

There are two critical spacecraft orbital events which must be commanded by the ground in order to execute aerobraking successfully. The first spacecraft event is performed every orbit around periapsis to configure and orient the spacecraft for entry into the atmosphere. This event is executed via initiation of a reusable command script which is resident on-board and stored in the mission phase script area of onboard memory. This drag pass command script is generated/updated by a ground resident command block called AEROBRAKE, which resides in the sequencing software. The on-board drag pass sequence is initiated via "start script" or trigger commands which are loaded as stored sequence command files as frequently as needed to meet navigation periapsis timing error prediction requirements. In addition to the sequence of trigger commands, the spacecraft attitude control software requires a Mars ephemeris in order to maintain the proper nadir attitude throughout the drag pass. The NAV Update Process is the process used for executing the drag pass event each orbit.

Associated with the AEROBRAKE block are specific parameters which allow the relative timing between the events to be adjusted as the orbit period decreases. Periodically, the block will be rerun on the ground to adjust the block timing and the resulting sequence reloaded on the spacecraft into the appropriate reusable script area. The Underlying Sequence Update Process is used to accomplish this.

Operations during this aerobraking mission phase will be as routine and repetitive as appropriate for safe and proper operation of the spacecraft. Six basic processes have been defined which will satisfy all commanding requirements. What follows is a brief description of each of these processes, including the frequency of their use and any teams involved. After the description of each of these processes a discussion of the manner in which these processes integrate together during aerobraking operations will be given.

NAV Update Process

The Nav update process is invoked regularly by the flight team to generate the commands required to trigger the onboard aerobraking drag pass script and to update the onboard ephemeris, which is required to maintain proper spacecraft drag attitude through the drag passes. The duration of this process varies with the experience level of the flight team. Early in aerobraking it will require seven hours to complete. This will be reduced to six hours during the middle of aerobraking operations and, toward the end of aerobraking operations, the process will be completed in five hours. One process cycle will be triggered by each periapsis until the orbit period is less than seven hours. After this time the one process cycle will predict more than one orbit ahead, which will avoid requiring more than one cycle running simultaneously. The teams involved in this process are SCT, NAV, SEQ and RTOT. The process also includes a review of the data to be uplinked and Mission Manager approval before the commands are radiated.

ABM Decision and Implementation Process

This process will be applicable to the small walkin maneuvers (AB2, AB3, AB4) and all corridor control maneuvers (ABMs). A single generic script which can perform these maneuvers will be stored in the mission script area of onboard memory. Parameters for this script will be determined and generated by using this process. The process begins with an independent assessment of current aerobraking operations by an Aerobraking Planning Group composed of the mission planning engineer and representatives from NAV and SCT. Within the bounds of operating guidelines defined by the project, this group collectively decides upon the timing and delta-V magnitude of the next ABM maneuver. If this group decided that an ABM maneuver is necessary, then the SCT will create a Spacecraft Activity Sequence File (SASF) containing the request/script trigger command. This group will also immediately forward its recommendation to the Mission Manager for final approval. If the Mission Manager concurs, then the SASF will be submitted by the SCT to the SEQ's Express Command (EC) process.

To expedite this process while reducing risk of miscommanding, a strategy has been implemented which uses a look-up table of the orbit argument of periapsis versus quaternion. The data contained in the table are derived from the aerobraking reference trajectory. From this trajectory it can be determined how the argument of periapsis changes over the time covered by the AB profile. From these data can be derived thrust vector information from which UP and DOWN quaternions can be generated. The current trajectory profile indicates that the argument of periapsis ranges in value from +160^{o} to -60^{o}. Two separate tables will be generated. One will be for UP maneuvers and the other will be for DOWN maneuvers. This helps reduce the risk of choosing the wrong direction quaternion set from a file containing both sets. An initial table will be generated pre-MOI (MOI-90^{d}), however, it may require updating after MOI if the MOI maneuver is significantly different from the planned MOI.

Finally, the magnitudes of the AB2-AB4 and ABM maneuvers will be quantized. This quantization will be for a "full" size maneuver, a "half" size maneuver and a "double" size maneuver. The actual numeric value of "full" may need to be updated occasionally to account for changes in walkin conditions or unexpected atmospheric conditions.

AB1 and TMO Maneuver Design Process

This process is used to design the AB1 and TMO maneuvers. The process begins with two full days of tracking data acquisition. This is followed by a period of orbit determination. The maneuver is then designed and expressed as a sequence input file (SASF). This file is processed through the sequencing system and data products are provided for flight team review and testing on the STL. Once the maneuver is verified through the sequencing system and the STL, the file will be submitted for Mission Manager approval. If approval is granted, then the maneuver will be sent to the spacecraft for storage onboard and eventual execution. The total duration of this process is 31 workhours (~4 workdays). It is performed during standard work shifts and only as needed to generate one of the above mentioned maneuvers. The participating teams are SCT, NAV, SEQ and RTOT.

Underlying Sequence Update Process

This process is invoked to update the Aerobraking script or the ABM Master script. It is also used to issue any special commands which may be necessary for operation of the spacecraft and for any commanding necessary to support science data collection. It is an off-line process. This means that it can be performed during a standard workday. It is expected to occur no more than once per week. The total duration of the process is 13 workhours. However, this is divided into two periods. The first is eight hours in length and is comprised of building the necessary sequence input files (SASF), completing their processing through the sequencing system, reviewing the resulting command files and initiating and executing a run of the STL. The final five hours, which occur on the following workday, are devoted to reviewing the STL run and obtaining final Mission Manager approval for radiation. The teams participating in this process are SCT, SEQ and RTOT.

The second critical spacecraft orbital event is the propulsive maneuver at apoapsis (ABM) which is executed as needed to maintain the required periapsis altitude. The ABM command script is generated by a ground resident command block called “ABM” and stored on-board the spacecraft similar to the drag pass script and is initiated via a real-time “start script” or trigger command. The ABM Decision and Implementation Process, is the process for executing an ABM.

Spacecraft Health Monitor Process

This process is used to monitor the daily health status of the spacecraft. It is a very simple and routine process which involves acquiring telemetry data from the spacecraft, analyzing the data and issuing reports pertaining to the health and status of the spacecraft. This process occurs daily during prime shift and requires approximately 2.5 hours to complete. The participating team is the SCT.

Atmosphere Modeling Process

This process is used to update the most current model being used for the Mars atmosphere. This process will analyze and review the existing Mars atmospheric model in use by the project, Mars Pathfinder atmospheric data, NAV provided atmospheric density data and SCT thermal and acceleration data to determine a more accurate model for the atmosphere. This new model will then be incorporated into the ABM Decision and Implementation Process to make possible the generation of updated Navigation files containing periapsis predictions for use during the NAV Update Process. This process will be used very infrequently. The process requires 2-3 days to complete.

All of the above processes must integrate together in a manner such that they do not require greater resources than are available on the flight team. Some processes are triggered by orbital geometric events (periapsis or apoapsis) while others are triggered by availability of certain data. Still other processes are performed off-line and will therefore always be performed during prime shift. The operations development team has analyzed the integration of these processes and has concluded that the flight team will be able to support aerobraking operations with only a small addition of resources in the NAVIGATION area (compared to the numbers given in the introduction). During the earlier phases of aerobraking most processes will be able to be performed during prime shift. Those which cannot will still only occur once per day and will require some personnel to work a modified single shift per day. However, once the orbital period is less than 24 hours some processes will be performed more than once per day. This will require more than one shift support per day for some teams. As the end of aerobraking approaches, the flight team will be working three shifts per day. This three shift per day period should last approximately one month.

Shown below is a representative integrated timeline of the flight team processes required for a 16 hour orbital period. The processes above the dashed line represent the processes which are performed on a as needed basis. The processes below the line are processes tied to spacecraft events at periapsis and apoapsis.

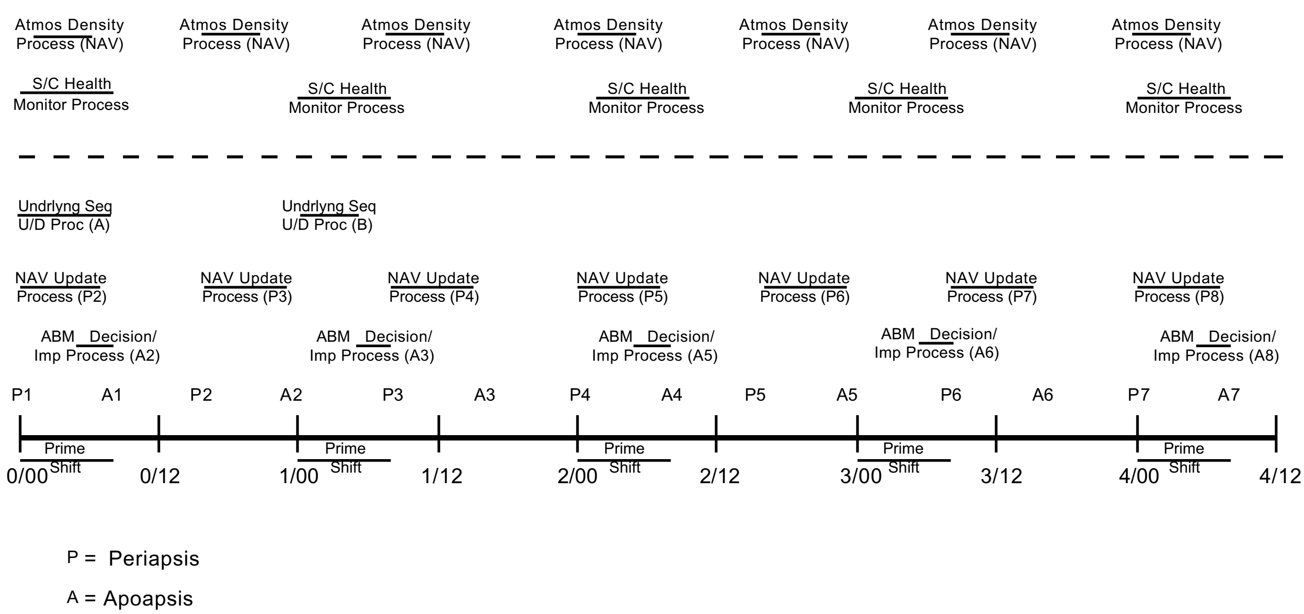


Figure 7-2
Integrated Aerobraking Operations Event Timeline

8.0 MAPPING OPERATIONS

In the mapping phase the spacecraft will operate in a two hour period, nearly polar, mapping orbit. Because the orbit is sun-synchronous with a 2:00 pm descending node, the spacecraft will be in eclipse for about 40 minutes each orbit. The spacecraft will be behind the planet as viewed from Earth for 0-40 minutes per orbit.

Mapping phase operations will be characterized by routine, repetitive data taking by the science instruments and routine spacecraft housekeeping activities. The science and engineering data will be recorded continuously on board the spacecraft and returned daily over a 10-hour 34-m HEF DSN tracking pass. Additional "real time" data will be returned in a second pass every third day. During a few selected weeks when the planetary geometry is favorable for radio science and imaging campaigns, the DSN coverage will be continuous.

The spacecraft will provide nadir pointing for the science instruments by means of a Mars horizon sensor. Backup pointing control is provided by a star scanner and an on-board spacecraft ephemeris. The ephemeris will be uplinked to the spacecraft weekly. This ephemeris also provides the information for providing the instruments with a pulse, or notification, of an upcoming equator crossing. A star catalog will be uplinked every two weeks.

The DSN will provide the Nav Team with daily (Monday-Friday) radiometric data files. The Nav Team will provide daily reconstruction of the spacecraft orbit for use by the science teams in their data analysis. Orbit predictions will be generated weekly for radiation to the spacecraft and for use in science activity planning.

Mapping phase maneuvers (Orbit Trim Maneuvers) will be infrequent. These maneuvers, which will adjust the orbit period to compensate for atmospheric drag effects and the orbit inclination to keep the orbit sun-synchronous, are expected to occur every two to three months.

For tailored maneuvers, those which require custom sizing for a specific end result, maneuver operations consists of an iterative process. Propulsion subsystem performance predictions are provided by the SCT to the Nav team, which designs a preliminary maneuver in terms of timing, duration, and pointing parameters based on Mission Planning requirements. The SCT then develops the execution parameters and spacecraft clock angle requirements based on power, thermal, and communications needs, and provides the command request. The sequencing team then builds the commands, STL verifies them, and MC transmits the command load after Mission Manager approval. In some cases, iterations are necessary between the Navigation and Spacecraft Teams to arrive at a mutually acceptable maneuver.

For untailored maneuvers, for example, those which might change periapsis altitude in discrete steps of equal and arbitrary size summing to the desired change, the process for a given maneuver size is the same as for the tailored maneuver. Once approved, however, the same maneuver can be made available for multiple usage at later times without recomputing burn duration or pointing.

An on-board "stored sequence" will operate the spacecraft over successive 28-day periods. The process for generating these sequences is described in the Cruise Operations Scenario. The mapping sequences will be simplified by the "autonomous eclipse management" strategy in which the spacecraft uses eclipse entry signals to trigger the commands necessary to operate the telecom and data collection activities.

The sequence will turn off the transmitter while the spacecraft is in eclipse each orbit in order to minimize the battery discharge. The sequence commands the telecom modes for the radio occultation ingress/egress events and the recorder for the record/playback activities. In addition, the changing Earth-Mars distance necessitates changing the record and playback rates four times over the mapping phase.

Mapping science will be accomplished by use of "non-stored" payload commands. The instrument teams will send commands, via JPL, to their instruments routinely, perhaps on a daily basis. These commands will act as instrument-internal "sequences" which will control data gathering and processing. Payload commands will be processed in an automated fashion once they reach the Project Data Base and sent to the spacecraft.

A small set of payload commands will require generation by the "stored sequence" process. These are commands that require exact timing issued by the spacecraft bus or commands that require use of spacecraft resources.

As in cruise, "non-stored" engineering commands can be sent to the spacecraft in the event of an anomaly. The process for preparing these commands is described in the Cruise Scenario.

The mapping phase will be interrupted for a two week period when Mars passes through conjunction on May 13, 1998. The spacecraft will operate autonomously without commanding over this period. The solar conjunction sequence will provide real-time spacecraft telemetry and radiometric data when the solar array is illuminated.

Mapping sequence development will be based on the Mission Plan and the Mission Sequence Plan. Any changes to these plans will require the approval of the Change Control Board which is chaired by the Mission Manager.

Mission Control support to the spacecraft for commanding and monitoring is similar to that described in the Cruise Scenario. Two principal differences will occur in mapping, however. First, the spacecraft will be out of radio contact, in "occultation", for up to 40 minutes minutes each orbit. Second, during the "Earth View Period" when the recorded data is being played back there will be no real-time engineering data to be monitored. Command verification for commands sent during these periods will be delayed until the playback has been completed.

The Spacecraft Team work during mapping will primarily consist of sequence preparation, review, and test, as well as spacecraft performance trending and extrapolation. The significant environments remain relatively constant, making frequent predictions unnecessary.

9. RELAY OPERATIONS

The relay phase is currently planned to be similar to mapping (with respect to spacecraft operations), except for the state of the experiment package. It is assumed that all experiments will be powered off, except for the Mars Relay (MR) and MOC. The MR will be set to beacon mode when over a lander site, to initiate lander data pickup. The lander will then transmit the data to the MR, where it will be relayed to the MOC for formatting and transmitted to earth real-time or stored on the solid state recorder for a later playback.   The relay operations are primarily for the Mars’98 lander, but will also potentially serve the M’01 lander as well.   The MGS will provide the only link to earth for the first three months post M’98 landing (as the M’98 spacecraft is aerbraking into the desired orbit). Upon completion of M’98 aerobraking, the MGS spacecraft will provide backup coverage for the lander.

During this phase alternate attitude selection will be required for the MGS spacecraft (to minimize desaturation fuel usage). These manuevers (known as the flip/flop maneuvers) will take place every other orbit and will be handled by a special block (to be built during the mapping phase).   Orbit trim maneuvers will be required about every 30 days and will be mini-sequenced into the on-board stored sequence, as they were in the mapping phase.

Additional navigation predicts will be required to determine when the spacecraft is over each landing site.   Low level commanding will be required to activate the MR.

10. CONTINGENCY OPERATIONS

Spacecraft activities are generally controlled by pre-planned events which are stored on-board as scripts or are initiated by non-stored commands radiated from the ground. The planning of these events are driven by the Mission

Sequence Plan, approved Change Requests or by Mission Manager approved real-time commanding. Occasionally, the spacecraft behaves in a non-predicted manner or a failure occurs on-board which may initiate on-board fault protection software and may require ground intervention to correct the problem and resume nominal mission operations. This anomaly response is made safer and more efficient with well thought out contingency plans.

MOS contingency planning typically involves the whole flight team in detection of the anomaly, retrieval of S/C telemetry around the time of the anomaly, analysis of this data, preparation of the anomaly response command files, re-planning the nominal mission and making the necessary management decisions in the course of the anomaly resolution.

The specific actions to be taken during an anomaly are governed by the specific anomaly the contingency plan documented in the Mission Operations Specification, Volume 11. Contingency plans, although often not directly applicable to the specific anomaly, provide typical checklists and activity flows to minimize omission errors caused by time criticality.

10.1 Anomaly Detection

S/C telemetry is reviewed and/or monitored by the Spacecraft Team and Mission Control. Typically, in real time, telemetry is monitored once per day by mission control unless the activities for a given pass are critical, in which case the SCT analysts will be actively monitoring the spacecraft. Non-real-time telemetry is also reviewed by the SCT. Thus detection of an anomaly may be in real-time or after-the-fact during the review of recorded and played back telemetry. Subtle anomalies may only be detected by long term trending of performance data.

Using established Telemetry Display Pages on the MSA workstations, channel alarms and predicts, anomalous spacecraft behavior is identified by the mission controllers, subsystems analyst or systems engineer. Detection of the problem typically results in the observer noting the time of the event, the S/C state leading up to the anomaly, the commands or activities the spacecraft was attempting to execute, all relevant telemetered data and error messages and whatever autonomous spacecraft response was executed. The criticality of the anomaly is established at this time.

For critical activities, specific contingency planning will be done beforehand and some pre-approved and tested contingency or express command files may have been approved, depending on their criticality and urgency.

10.2 Notification

The purpose of prompt notification is to inform the required technical and management personnel of the anomaly such that the appropriate response can be made expeditiously and safely. The affected subsystem, systems, ground systems and management authorities will be contacted based on a pre-established on-call list maintained at the mission controller's console and within the SCT area. The priority of notification may change depending on type of anomaly and mission urgency, but typically the SCT Chief and Mission Manager are notified soon after the detection and informed of the status of the anomaly and recommendation from the real time area.

The SCT Chief will notify the required subsystem analysts of the situation and start making arrangements for the anomaly response. Based on urgency and need for augmented resources the Mission Manager shall notify the appropriate MOS organizations and make arrangements for their support. Typically this would include obtaining more DSN coverage and obtaining command file generation support. Notification may be made through commercial telephone lines, established voice nets or pre-assigned pagers.

10.3 Immediate Response

The immediate response phase is focused on stabilizing the S/C, accumulating as much data about the anomaly as possible and minimizing any permanent loss of S/C capability. The principle objective is to prevent further S/C damage. A key concern during this phase is to not to exacerbate the current failure nor induce another failure by reacting too hastily or without sufficient knowledge of the S/C condition.

Typical responses may be to configure the uplink and downlink components to establish a reliable two-way link to the spacecraft for commanding and telemetry, optimize data return by selection of the engineering telemetry mode, read out memories or solid state recorder contents, ensure proper power generation and load states, adjust heater loads such that components are within survivability limits, and prevent unnecessary/unwanted autonomous actions by the S/C. These immediate response actions will be made with the approval of the Mission Manager unless a pre-approved response exists and there is a level of urgency such that delaying this response could expose the S/C to unacceptable risk.

An outcome of this phase is a preliminary explanation of the cause of the anomaly. An Incident, Surprise, Anomaly (ISA) Report will be written during this time frame describing the symptoms and believed cause of the problem. On MGS an electronic problem reporting tool will be utilized which includes the capabilities of having data stored in an electronically interactive and accessible database. Throughout the contingency process the initiated ISA will be updated routinely in order to provide the status of an anomaly through the database.

10.4 Project Status

An anomaly status meeting will be initiated as soon as possible after the anomaly has been identified. Given the SCT location in Denver, this meeting will be a tele- or video conference.

The following information shall be presented to representatives of affected MOS organizations and project management as it becomes available. Team Chiefs and Mission Manager at a minimum will be present.

a. Specify the current state of the S/C.
b. Identify the probable cause of the anomaly.
c. Identify possible damage and loss capabilities.
d. Specify any known, residual vulnerabilities and risks.
e. Describe autonomous actions (fault protection) taken by the S/C.
f. Discuss ground actions and responses taken.
g. Identify the status of corresponding contingency plans/command files.
h. Identify further response actions, recommended follow-on activities and a preliminary schedule.

The outcome of the anomaly status meeting will be a near term direction for the project to take to resolve the anomaly. Team assignments will be made to allow for the resolution of the anomaly. Management will be required to secure the necessary operations and facility resources to continue the problem resolution, and the operations teams will be required to follow the appropriate, specific contingency plans or develop a plan which fits the situation.

10.5 Analysis and Resolution

The SCT during this phase will continue to analyze the anomaly, maintain the spacecraft in a safe state, and, once the spacecraft current capabilities are re-established and impacts to the mission plan are known, re-configure the S/C to the mission restart state. Other MOS teams will support the recovery efforts, typically in the areas of realtime monitoring telemetry (MC & SCT), building recovery command files (Sequence Team) and re-planning mission events suitable to the post anomaly capabilities of the S/C and affected mission events (Mission Planning).

The tools and facilities which may be utilized are the telemetry (real-time and archived) memory readouts, S/C analysis tools, MGSO data processing and collection facilities, sequencing and mission planning tools, archived contingency command files, operations contingency plans, STL simulations and S/C tests as appropriate. Candidate scenarios, root causes, and optimum long-term actions will be determined. Actions may include hardware reconfigurations, ground and/or flight software modifications, and replanning due to degraded capabilities or life issues.

The ISA report will be routinely be updated with current status from all MOS teams assigned actions which will provide overall status regarding progress on the anomaly. Also, status meetings may be called by the Mission Manager to give more in-depth and consolidated status of the integrated MOS anomaly resolution.

10.6 Anomaly Closeout

The closeout of the anomaly shall require closure of the ISA per the appropriate process. If flight hardware failed a Problem Failure Report (PFR) must be filed and processed. Depending on the severity of the anomaly, a failure review may be conducted to discuss all aspects and impacts of the anomaly on the spacecraft and mission. Typically this review would be conducted internal to the project, but in more severe cases, reviewers from outside the project could be brought in to review the results.

For anomaly closeout it is important to understand what caused the failure, so that changes affecting S/C capabilities, procedures, documentation, contingency plans, can be made to optimize mission science return. Therefore, closeout may initiate change requests to team contingency plans, team procedures, the ground system and future stored sequences.